Assessing Hazard Vulnerability in Troutdale

Spring 2021
Troutdale

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PPPM 495/595 Advanced Urban Geographic Information Systems

UNIVERSITY OF OREGON
THE CITY OF TROUTDALE OREGON
SCI Sustainable Cities Institute
SCYP Sustainable City Year Program

Spring 2021 Troutdale

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This report represents original student work and recommendations prepared by students in the University of Oregon's Sustainable City Year Program for the City of Troutdale. Text and images contained in this report may not be used without permission from the University of Oregon.

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About SCI

The Sustainable Cities Institute (SCI) is an applied think tank focusing on sustainability and cities through applied research, teaching, and community partnerships. We work across disciplines that match the complexity of cities to address sustainability challenges, from regional planning to building design and from enhancing engagement of diverse communities to understanding the impacts on municipal budgets from disruptive technologies and many issues in between.

SCI focuses on sustainability-based research and teaching opportunities through two primary efforts:

1. Our Sustainable City Year Program (SCYP), a massively scaled university-community partnership program that matches the resources of the University with one Oregon community each year to help advance that community's sustainability goals; and

2. Our Urbanism Next Center, which focuses on how autonomous vehicles, e-commerce, and the sharing economy will impact the form and function of cities.

In all cases, we share our expertise and experiences with scholars, policymakers, community leaders, and project partners. We further extend our impact via an annual Expert-in-Residence Program, SCI China visiting scholars program, study abroad course on redesigning cities for people on bicycle, and through our co-leadership of the Educational Partnerships for Innovation in Communities Network (EPIC-N), which is transferring SCYP to universities and communities across the globe. Our work connects student passion, faculty experience, and community needs to produce innovative, tangible solutions for the creation of a sustainable society.

About SCYP

The Sustainable City Year Program (SCYP) is a year-long partnership between SCI and a partner in Oregon, in which students and faculty in courses from across the university collaborate with a public entity on sustainability and livability projects. SCYP faculty and students work in collaboration with staff from the partner agency through a variety of studio projects and service-learning courses to provide students with real-world projects to investigate. Students bring energy, enthusiasm, and innovative approaches to difficult, persistent problems. SCYP's primary value derives from collaborations that result in on-the-ground impact and expanded conversations for a community ready to transition to a more sustainable and livable future.

About City of Troutdale

Troutdale is a dynamic suburban community in Multnomah County, situated on the eastern edge of the Portland metropolitan region and the western edge of the Columbia River Gorge. Settled in the late 1800s and incorporated in 1907, this "Gateway to the Gorge" is approximately six square miles in size with a population of nearly 17,000 residents. Almost 75% of that population is aged 18-64.

Troutdale's median household income of $72,188 exceeds the State of Oregon's $59,393. Troutdale's neighbors include Wood Village and Fairview to the west, Gresham to the south, and unincorporated areas of Multnomah County to the east.

For the first part of the 20th century, the city remained a small village serving area farmers and company workers at nearby industrial facilities. Starting around 1970, Troutdale became a bedroom community in the region, with subdivisions and spurts of multi-family residential housing occurring. In the 1990s, efforts were made to improve the aesthetics of the community's original core, contributing to an award-winning "Main Street" infill project that helped with placemaking. In the 2010s, the City positioned itself as a jobs center as it worked with stakeholders to transform a large superfund area to one of the region's most attractive industrial centers – the Troutdale-Reynolds Industrial Park.

The principal transportation link between Troutdale and Portland is Interstate 84. The Union Pacific Railroad main line runs just north of Troutdale's city center. The Troutdale area is the gateway to the famous Columbia River Gorge Scenic Area and Sandy River recreational areas, and its outdoor pursuits. Troutdale's appealing and beautiful natural setting, miles of trails, and parkland and conservation areas draw residents and visitors alike. The City's pride in place is manifested through its monthly gatherings and annual events, ranging from "First Friday" art walks to the city's long-standing Summerfest celebration each July. A dedicated art scene and an exciting culinary mix have made Troutdale an enviable destination and underscore the community's quality of life. Troutdale is home to McMenamins Edgefield, one of Portland's beloved venues for entertainment and hospitality.

In recent years, Troutdale has developed a robust economic development program. The City's largest employers are Amazon and FedEx Ground, although the City also has numerous local and regional businesses that highlight unique assets within the area. Troutdale's recent business-related efforts have focused on the City's Town Center, where 12 "opportunity sites" have been identified for infill development that respects the small-town feel while offering support to the existing retail environment. The next 20 years promise to be an exciting time for a mature community to protect what's loved and expand opportunities that contribute to Troutdale's pride in place.

Course Participants

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Executive Summary

In this report, students helped address Troutdale's goal of understanding potential hazards and the social vulnerability associated with such risks. Students collaborated in four research groups to collect data and analyze the potential for hazard susceptibility in the City. Students employed a variety of methods to inform their research including:

- Literature review of selected hazard plans
- Collecting and analyzing U.S. Census and GIS data
- Local resources, including conversations with City planning staff and other professionals in related fields

Groups were each assigned one of four hazards to research and analyze: wildfire, flooding, landslide, and earthquake/liquefaction. According to the final comprehensive analysis, it was determined that the city of Troutdale has low hazard susceptibility. Overall:

- Wildfire susceptibility is low. However, three main regions of high burn susceptibility exist: along the east of the Sandy Riverfront, near the McMenamins Edgefield/Halsey Corridor, and a free-standing area located in Troutdale's southeast.
- Flood susceptibility is low. Susceptibility is highest near rivers, particularly on the east side of Sandy River and along Beaver Creek.
- Landslide susceptibility is low, with the highest susceptibility area on the eastern extremity of Troutdale's city limits.
- Liquefaction susceptibility is relatively high. The high susceptibility area is located on the north side of Troutdale, near the Columbia River, and along the Sandy River and Halsey Street.

Despite overall low hazard susceptibility, students established recommendations for increasing citizen resources and infrastructure safety and resilience. Increased education and awareness of the existing hazards can benefit residents ability to prepare for emergencies especially residents in high-hazards areas with greater social vulnerability. Additionally, Troutdale could mitigate and prepare for hazards by identifying funding for building and infrastructure retrofitting, establishing and placing signs that indicate alternate routes for emergencies, and adopting land use codes to limit future development in high hazard areas. Finally, due to growing tourism in the areas located within high hazard areas, Troutdale could benefit from developing a plan to communicate dangers and respond to the needs of visiting tourists in the face of emergencies.

Introduction

PROJECT BACKGROUND AND RESEARCH OBJECTIVES

Global climate change has increased the frequencies and the severity of communities' exposure to natural hazards. Communities in the Northwest have become increasingly vulnerable to hazards such as wildfire, flooding, landslide, and earthquakes. Risk assessment is an important step in a community's effort to devise effective and efficient hazard response strategies.

The goal of this report is to identify areas of Troutdale with higher exposure to natural hazards and map their spatial distribution. Locating these hazards spatially, students were able to understand the economic and social impacts of the particular hazards on the City and community. Further efforts sought to inventory impacted facilities, infrastructure, and natural resources. Vulnerable populations were also identified in relation to their proximity to different hazards and their exposure levels. Research objectives included:

- Mapping the spatial distribution of four hazard risks to understand hazard exposure in and around Troutdale.
- Locate community assets and inventory potential economic loss to facilities and economic assets in relation to hazard threats.
- Inventory affected facilities and estimate economic loss.
- Examine the location of vulnerable community members in relation to hazard risk levels.
- Provide recommendations for the city of Troutdale to mitigate potential damage and risk posed to vulnerable populations.

THEMES

This report aims to map the spatial distribution of hazard risks and assess their economic and social impacts from the four types of natural hazards in the city of Troutdale.

Based on initial conversations conducted with city of Troutdale planners, four hazards were identified: wildfire, flooding, landsides, and liquefaction (earthquakes). Susceptibility or risk levels were developed for each of these hazards.

According to the U.S. Geology Survey, risk can be thought of as "the intersection between hazards and assets" (Wood 2011). Assets encompass "all the things that make a community livable, including the people, land use/zoning and buildings, critical facilities, and primary infrastructure such as transportation corridors, electrical transmission lines, dams, and so on" (Wood 2011). The National Risk Index methodology provides a more comprehensive definition of "risk" that takes into consideration social vulnerability and community resilience, both of which are measured with demographic characteristics.

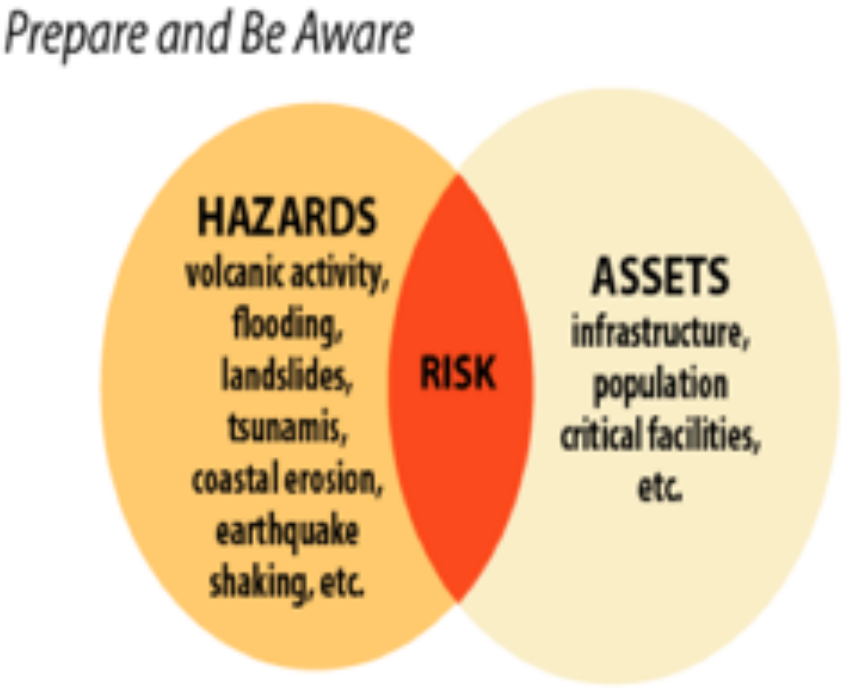


FIG. 1-1
Risk as the intersection between hazards and assets

Community assets included economic assets, critical infrastructure, critical facilities, and natural resources. Economic assets were defined as anything that created revenue for Troutdale. This report considered critical infrastructure as transportation infrastructure, emergency services, and utilities such as sewer pump stations, substations, transmission lines, water pipes, sewage pipes, and natural gas lines. When examining critical facilities, the following were analyzed: childcare facilities, nursing homes, mobile home parks, places of worship, public schools, and cultural places.

Social vulnerability factors contribute to an individual and community's resources to anticipate, survive, and recover from natural hazards and disasters. While an array of indicators can be used to analyze social vulnerability, this report focused on four: elderly populations 65 years and over, young populations under 18 years, differently or alternately abled populations, and populations below the poverty line.

STUDENT WORK AND RESEARCH METHODS

Students met with city of Troutdale planning staff to focus research on their hazards of highest concern and to provide pertinent information to guide research. Four groups were created to conduct initial research, gather data, conduct analyses, and provide recommendations.

Students examined several existing resources to provide valuable context and background on how other hazard plans are developed nationally. In addition, professionals were asked to present on their work, answer student questions, and provide resources. Resources include:

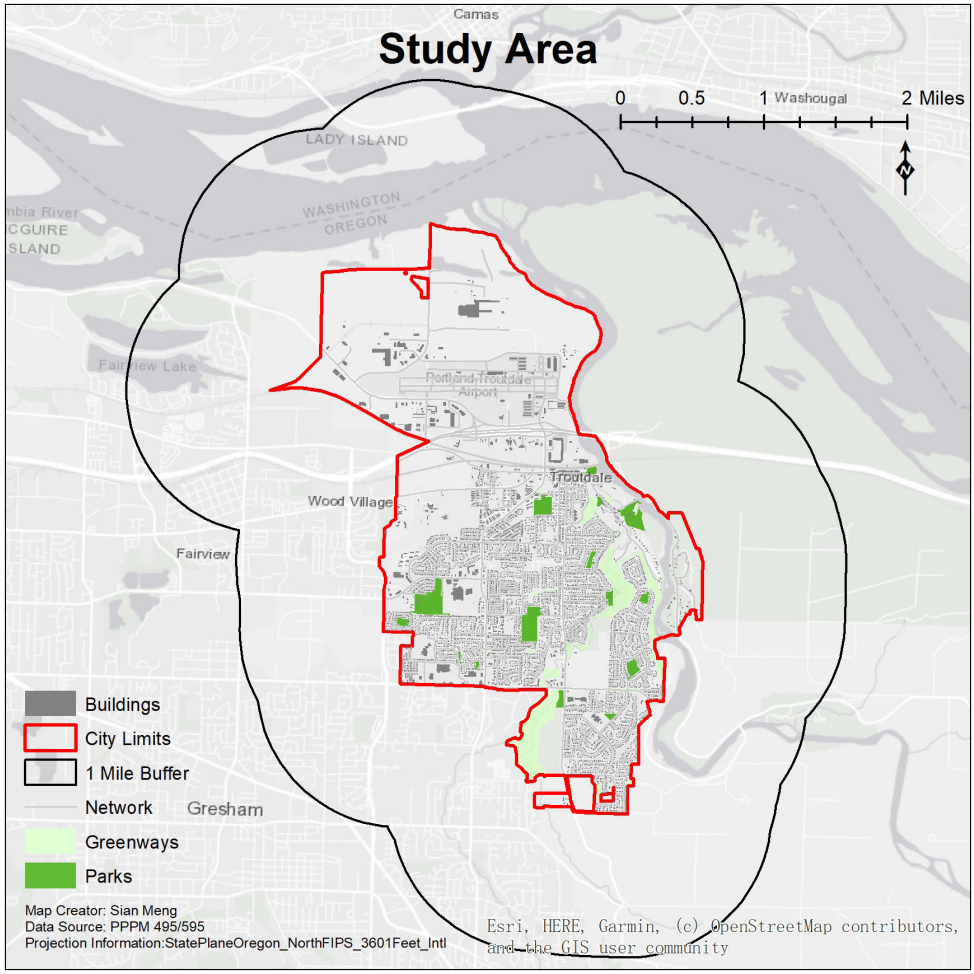
- Center for Disease Control's Social Vulnerability Index Interactive Map
- Multnomah County Multi-Jurisdictional Natural Hazards Mitigation Plan
- National Risk Index for Natural Hazards
- University of South Carolina's Hazards & Vulnerability Research Institute's Social Vulnerability Index for the United States
- U.S. Department of Homeland Security's G318 Local Mitigation Planning Workshop: Mitigation Strategy

EXPLANATION OF STUDY AREA

This report's study area began with the city of Troutdale's city limits (Figure 1-2). However, initial conversations with Troutdale planners led us to reconsider the area of analysis upon which to focus. City planners brought to students' attention that the unincorporated area to the east of the city limits is experiencing growth and expansion. While not formally within the boundaries of the City, this population is nonetheless dependent on the resources provided by Troutdale. With this additional information, it was decided that the research analysis should include a one-mile buffer area around the city limits to accurately represent the threats and utilization of critical infrastructures and facilities.

Analysis of social vulnerability required further consideration of the study area. U.S. Census data was used to gather population information, predominantly using Census block groups. However, block groups do not perfectly align with city limits, which necessitated an additional decision on which block groups would best represent the population within Troutdale. The block group in the most northern area of Troutdale was not included as it predominantly is an industrial area, and, as this block group extends to the west, it primarily represents non-Troutdale residents. The lower-right and the lower-left block groups were included even though their boundaries extended beyond the city limits because tax lot data demonstrated that most of the residential area still lie within the city limits. Finally, the large block group that extended beyond the city limits to the east was also included as most residents in this block group still live within the city limits and because it is identified as an area whose population is dependent on Troutdale.

FIG. 1-2
Boundaries used in study



DATA SOURCES

To analyze the hazard vulnerability of Troutdale, data were obtained from various sources.

Wildfire

- Oregon Wildfire Risk Explorer
- Oregon Department of Geology and Mineral Industries

Flood

- Federal Emergency Management Association

Landslide

- Statewide Landslide Information Database for Oregon

Liquefaction

- Statewide Landslide Information Database for Oregon
- Oregon Statewide Geohazards Viewer

Social vulnerability indicators data were acquired through:

- 2019 U.S. Census Data (block group)
- 2019 American Community Survey Data (5-year average)

We were aware of the potentially high margin of error in analyzing social vulnerability by using block group data due to their large size relative to

Troutdale. However block groups were the only ones that contained the data we prioritized representing based on research from other social vulnerability indexes used nationally. These indicators help communicate where there are concentrations of people who may require additional services and support should a hazard event occur.

Finally, the critical infrastructure used in this analysis was largely provided by the city of Troutdale Planning Department, as well as the majority of the critical assets data. Additional information was gathered using Google Point of Interest (POI) data which generated roughly 90 unique categories, some of which were included in this analysis. The POI data was then mapped on files obtained from Homeland Infrastructure

FOUNDATION LEVEL DATA: METHODOLOGY AND ANALYSIS

Upon obtaining hazard data, the data required the development of probability or threat levels. Wildfire, landslide, and liquefaction data generated four levels: none, low, medium, and high. Dialogue with Troutdale planners guided final flood threat level categorization to three threat levels: floodway, 100-year flood zone, and 500-year flood zone.

To analyze the risk of hazard threats upon Troutdale, community assets were located and inventoried. The categories used for this analysis included economic, critical infrastructure, critical facilities, and natural resources. After these data were located, the data were placed in relation with the hazard data to calculate the potential of loss based on each hazard and hazard level.

With these data in place, social vulnerability data was gathered. Researching existing social vulnerability indexes allowed us to identify the most pertinent social vulnerability indicators and four data points were decided upon: the elderly population over 65, children under 18, alternately abled or disabled population, and people below the poverty line. Placing these populations in relation to the hazard probability data, vulnerable populations were located in Troutdale.

The analysis process was iterative and began with a hazard assessment of Troutdale and the surrounding 1-mile area. After looking at the liquefaction exposure on its own, we mapped the social vulnerability indicators to understand where vulnerable populations were concentrated spatially. Following this, we mapped point and polygon shapefiles of Troutdale's community assets. Once these were all mapped individually and their spatial distribution was examined, we layered the social vulnerability and community assets on top of the hazard exposure layer to see if vulnerable populations were in high exposure areas. This also helped identify the economic value of critical infrastructure at different exposure levels. The findings from this analysis process follow.

FINAL DELIVERABLES

This report provides overviews of the hazard, community asset, and social vulnerability analyses as defined by the city of Troutdale. Maps assess and communicate the various level of hazard risk within the city of Troutdale. Tables are included when believed to best represent the information. Finally, our conclusion includes suggestions and recommendations from our teams on how the city of Troutdale can best prepare for future threats of hazards.

Wildfire

FIG. 2-1
Wildfire
Image of Eagle Creek Fire taken from Washington side of Bonneville Dam on Monday, Sept. 4, 2017
Photo by Tristan Fortsch via KATU News

OVERALL HAZARD RISK

Wildfire are fires caused by nature or humans that result in the uncontrolled destruction of forests, brush, field crops, grasslands, and property (Wildfire n.d.). Based on the wildfire risk susceptibility data, Troutdale is in the lowest category for burn probability in the state of Oregon; 0 to 0.0001 or 1 in 10,000 (DOGAMI 2021). For comparison, the highest burn susceptibility category in Oregon is 1 in 500 (Gilbertson-Day 2018). Buffers were used to generate burn susceptibility zones within Troutdale to represent the spreadable nature of wildfires and provide more detailed data for Troutdale.

The Euclidean distance from the areas with a greater than zero burn probability value generated four susceptibility zones: areas with a burn probability greater than zero constitute high burn susceptibility, areas less than 200 ft away constitute moderate burn susceptibility, areas 200 to 500 ft away constitute low burn susceptibility, and areas beyond 500 ft away constitute no burn susceptibility.

The majority of high burn susceptibility area exists across the Sandy River from Troutdale and into the Columbia River Gorge. Within city limits, three main regions of high burn susceptibility exist. These areas of high burn susceptibility are: along the Sandy Riverfront to the east, near McMenamins Edgefield/Halsey Corridor, and free-standing area located in Troutdale's southeast.

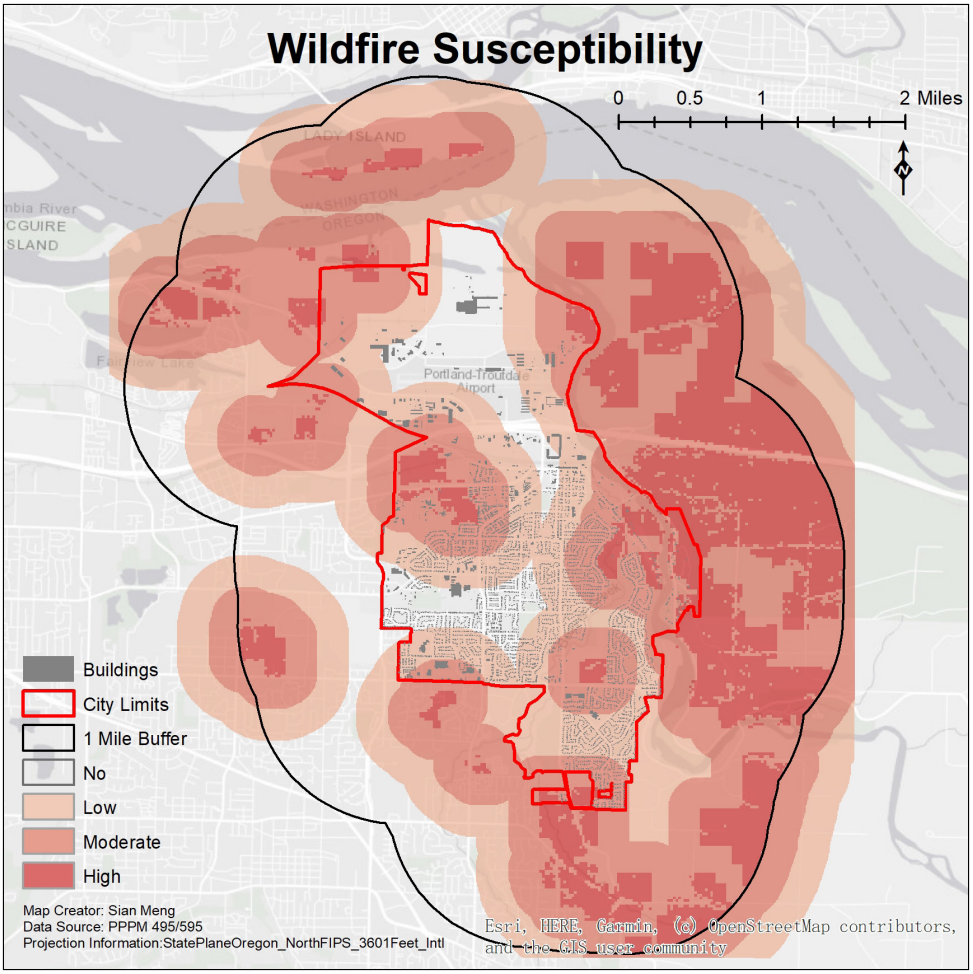


FIG. 2-2
Overall Burn Susceptibility Map

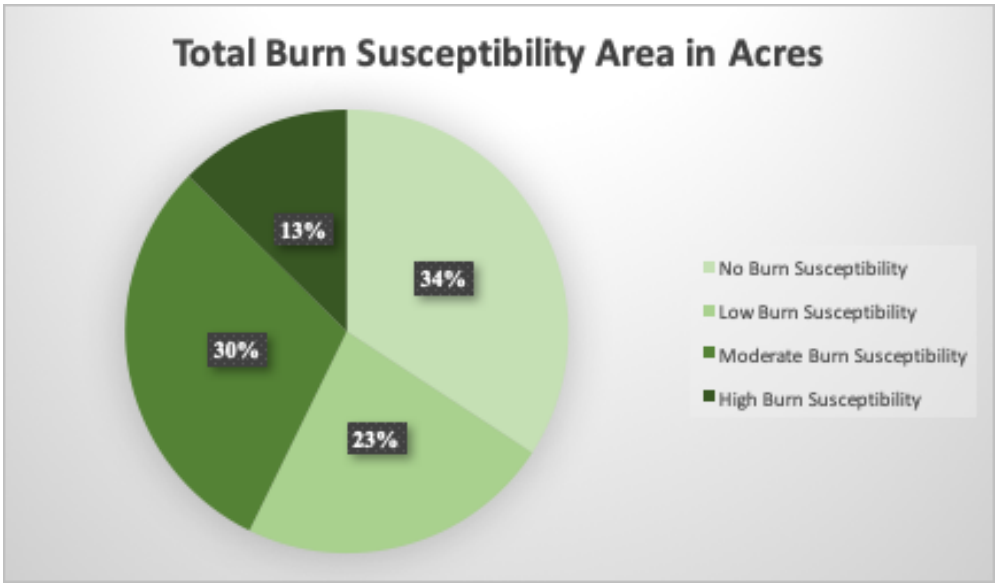


TABLE 2-3
Total Burn Susceptibility Area in Acres

COMMUNITY ASSETS

Two of Troutdale's economic assets were identified with high burn potential risk: the major tourist attractions of McMenamins Edgefield and Glenn Otto Community Park. However, Troutdale has no critical facilities located within high burn potential risk. It is important to note the commercial and residential buildings located in high burn susceptibility zones are an estimated $100 million in economic value, as seen in Table 2-4.

TABLE 2-4

Community Economic Assets Impact in High Susceptibility Zones

Community Assets in High Susceptibility Zones	Estimated Economic Value
Commercial Buildings	$ 59,715,660
Residential Buildings	$ 38, 075,410
Mobile Home Parks	$ 0
Agricultural Lands	$ 2,222,070

The majority of Troutdale critical infrastructure is located outside of the high burn susceptibility zones with some exceptions. Only 3.5 miles of Troutdale's roads and 0.8 miles of its railroad lie within a high susceptibility zone. Utilities, frequently placed at the same time and place as public roads, share similar exposure to high wildfire risk. Notably, 1.3 miles of water pipes, 1.0 miles of sewer pipes, and 0.2 miles of natural gas line are present in high burn susceptibility areas. Further critical infrastructure analysis reveals that 3% of emergency facilities, mostly shelter facilities, exist in high burn susceptibility zones.

TABLE 2-5

Critical Infrastructure Impact in High Susceptibility Zones

Critical Infrastructure in High Susceptibility Zones	Estimated Impact
Roads	3.5 miles
Railway	0.8 miles
Bridges	0
Airports, Boating, and Port Facilities	0
Sewer Pump Stations	0 miles
Water Pipes	1.3 miles
Sewer Pipes	1.0 miles
Natural Gas Lines	0.2 miles
Transmission Lines	0 miles

Troutdale's natural resources is the only sector of community assets that is significantly at risk of burning in a wildfire. By acreage, 73.4 acres of Troutdale's greenways are in the high susceptibility zone. Additionally, 4,103 acres of agricultural land located within the city limits are located in the high burn susceptibility zone. This analysis does not include the agricultural land that located within the one-mile buffer of the City. Further analysis could clarify this potential risk as it does include a high number of agricultural lots.

TABLE 2-6

Natural Resources Impact in High Susceptibility Zones

Natural Resources in High Susceptibility Zones	Estimated Impact
Parks	0 acres
Greenways	73.4 acres
Agricultural land	$2,222,070

SOCIAL VULNERABILITY

A small percentage of Troutdale's population (5%) reside within a high burn susceptibility zone.

Youth populations are concentrated in western Troutdale, near the Edgefield/Halsey Corridor cluster of high burn susceptibility zones. Elderly populations are concentrated to the east, immediately adjacent to the cluster of high burn probability zones along the Sandy River. Based on these observations, these vulnerable populations are at substantial risk to wildfire.

The eastern portion of the City is much more exposed to burn susceptibility. As seen on the map, many buildings are in the moderate probability zone, with some extending into the adjacent high susceptibility zones. These areas, while containing lower concentrations of vulnerable populations, were identified as a priority because they have higher levels of exposure.

DISCUSSION AND RECOMMENDATIONS

Our analysis concludes that the overall wildfire burn susceptibility in the city of Troutdale is very low. Only a small portion of the City has a susceptibility of burning (less than 0.01%).

Troutdale could focus attention on vulnerable tourist destinations and agricultural land in the face of wildfire susceptibility. Elements of the built environment such as transportation and utilities infrastructure, critical facilities, and residential and commercial buildings are not in significant danger of burning. Despite this low overall risk, special attention could be given to the following community assets, which are at some risk of burning: tourist destinations McMenamins Edgefield, Glenn Otto Community Park, as well as agricultural lands, greenways, and parks. In our assessment of Troutdale residents' wildfire risk, it was affirmed that vulnerable populations will be impacted most by wildfire, whether

in the city limits or nearby. Special consideration could be taken in building resilience to all hazards in the areas these residents are concentrated.

Though the risk of wildfire is low, the Department of Geology and Mineral Industry (DOGAMI) officials explain that the susceptibility of wildfire is much greater than 1 in 10,000 when the impacts of regional wildfires, such as evacuation traffic and populations, air quality, etc. are considered. Therefore, not only are the high burn susceptibility zones of Troutdale at risk, all surrounding areas are potentially at risk.

Flooding

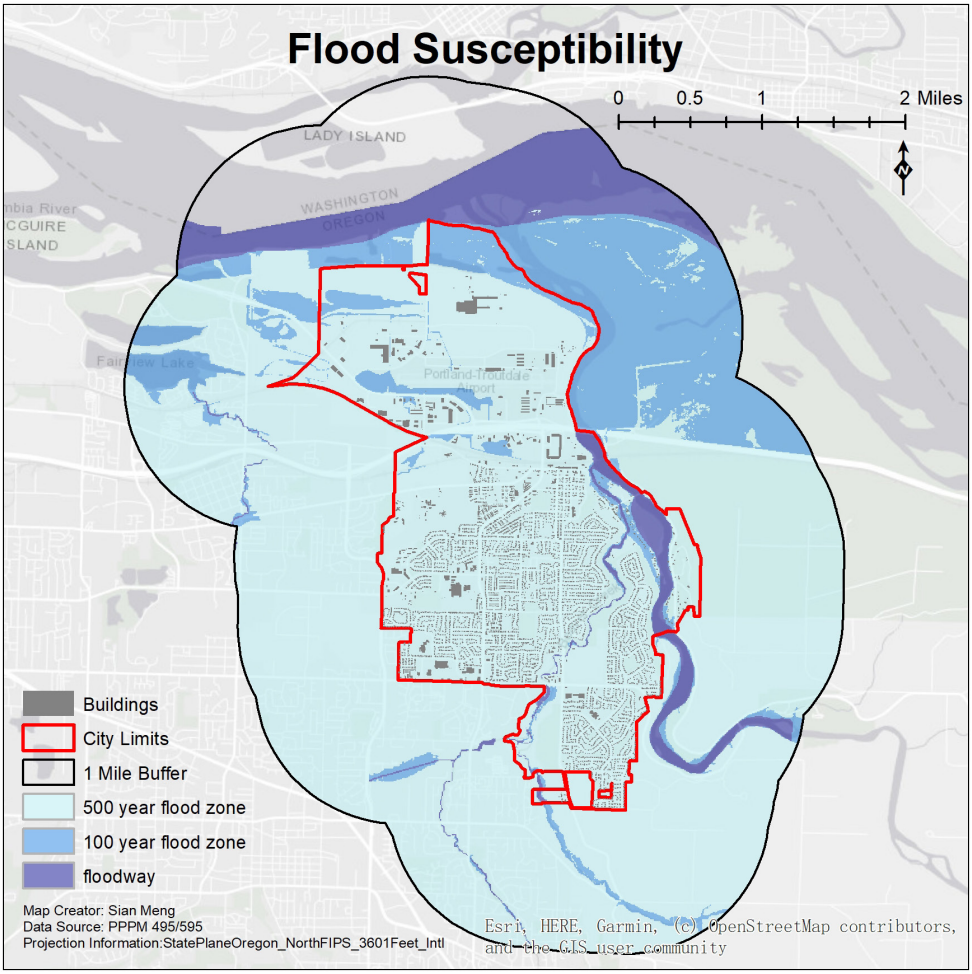
FIG. 3-1
Flooding
The Wall Street Journal

OVERVIEW

Floods are a rising and overflowing of a body of water onto dry land. Floods can cause loss of life and damage to structures, crops, land, flood control structures, roads, and utilities. Floods can also cause erosion and landslides (Flood n.d.). Flood susceptibility uses three main criteria: severity (defined as magnitude, duration, and extent of flooding), probability of occurrence, and the speed of flood onset. Troutdale's flood hazards were placed into three categories: the floodway, 100-year flood zone, and 500-year flood zone, or high, mid, and low susceptibility, respectively.

The floodway is the highest susceptibility of flooding and encompasses the area on either side of a river's channel, serving as a natural conduit for floodwaters. This area on average experiences flooding every second spring. The 100-year flood zone is considered medium risk based on the susceptibility of flooding, defined as any area with a 1 in 100 (1%) chance of flooding every year. The 500-year flood zone is considered low to no risk since this area has a 1 in 500 (0.2%) chance of flooding each year (FEMA 2021).
The areas in Troutdale with the greatest susceptibility of flooding are near rivers, particularly on the eastern side of Sandy River but also along Beaver Creek. Outside of the city limits, but within the one-mile buffer, is the Columbia River floodway. The 100-year flood zone of the Columbia is directly to the east of Troutdale.

FIG. 3-2
Overall flood susceptibility map



COMMUNITY ASSETS

Troutdale's economic assets have one identified high-flood susceptibility: Glenn Otto Community Park, a tourist attraction, is located within the high susceptibility zone. Troutdale could improve its resilience to flooding due to the nature of the asset. There are no major employers or community facilities in the medium or high hazard zones. Additionally, due to pre-existing zoning that limits development in floodways and 100-year flood zones, there are no buildings in a floodway.

TABLE 3-3

Community Economic Assets Impact in High Susceptibility Zones

Community Assets in High Susceptibility Zones	Estimated Impact
Major Employers	0
Tourist Destinations	1
Commercial Buildings	$ 0
Residential Buildings	$ 0

No community facilities were found in high or even medium flood susceptibility zones. Features that may require further analysis are utility lines and transportation routes, both of which have sections that cross high-risk zones. The transportation infrastructure located in high susceptibility zones includes two bridges and one boating facility (Figure 3-4). It is unclear from our analysis whether this infrastructure is truly at risk or if it was engineered to withstand floods. Within Troutdale's city limits, no natural resources are located in the high flood susceptibility zone besides Glenn Otto Community Park, mentioned above.

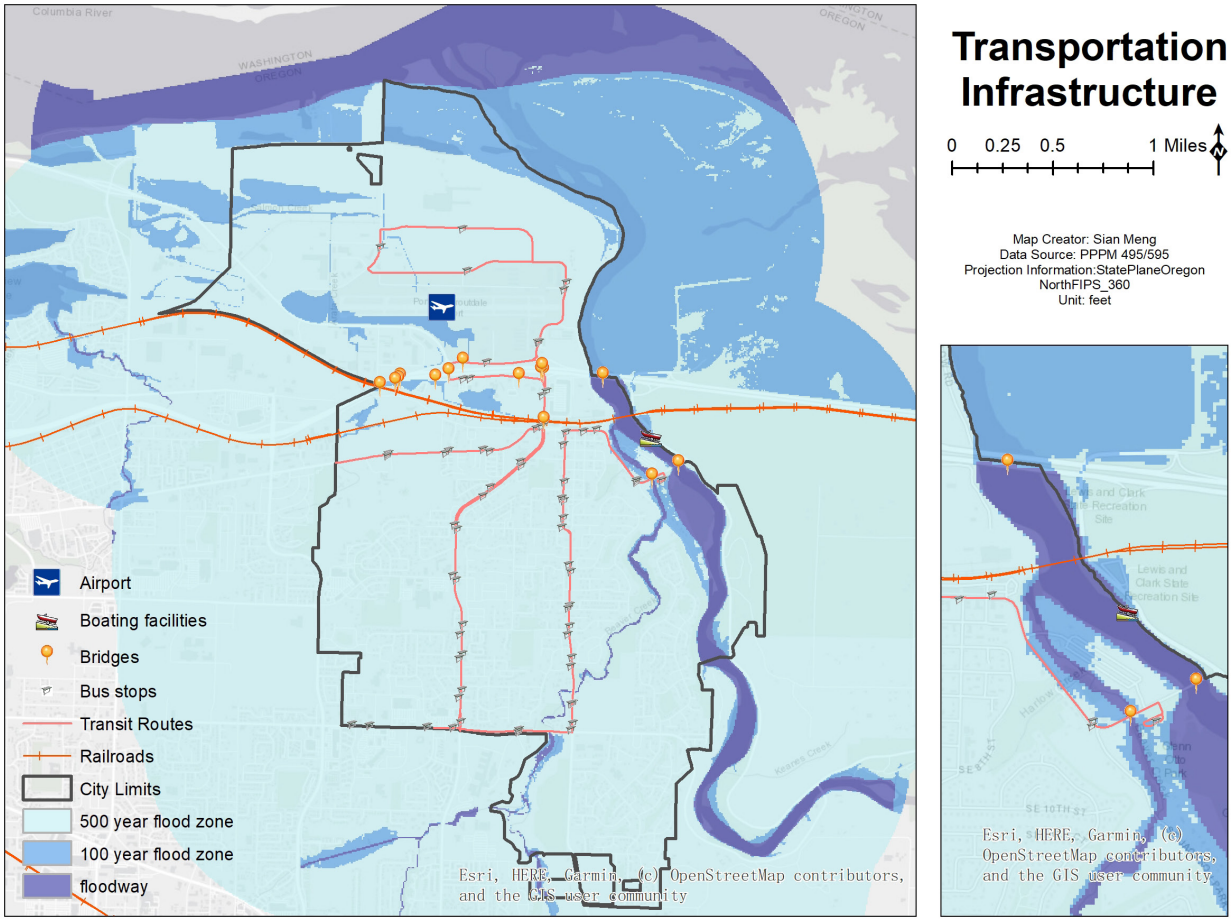


FIG. 3-1
Transportation infrastructure

SOCIAL VULNERABILITY

Using U.S. Census block group data, vulnerable populations were identified in relation to hazard susceptibility levels. Although three block groups intersected with Troutdale's Sandy River high-susceptibility area, no residential buildings were located in the high-risk areas. However, the block group to the east of Troutdale, which represents a small portion of the city limits, does have a higher elderly population with some of the elderly population (2%) residing in a high flood susceptibility zone.

DISCUSSION AND RECOMMENDATIONS

Our analysis finds that Troutdale has a low-overall flood risk.

Further research would contribute to a better understanding of the potential impact of flooding on one of the City's significant tourist destinations, Glenn Otto Community Park, and the damage to surrounding businesses that are not located within the flood zone but are dependent on the park's high usage. The city of Troutdale could also investigate the extent at which the utility lines and transportation routes were engineered with consideration of the high- susceptibility zones they pass through.

The GIS analysis we conducted used the center of buildings to designate location in a susceptibility zone. Because of this, buildings that are partially located in the high-susceptibility zone were not classified as such, although the majority of those residences are also located in the mid-risk zone. Troutdale could provide information and resources to the residences that have a mixed-level susceptibility, especially those residences that have a high-susceptibility for damage on some of their property.

The Multnomah County Natural Hazards Mitigation Plan (MCNHMP) lists Troutdale with a moderate risk of flooding, the second highest designation. A substantial portion of the MCNHMP focuses on the risk from channel migration of the Sandy River, a topic not included in our analysis. According to the MCNHMP, the Sandy River has a history of channel migration (documented in DOGAMI's Open-File Report O-13-10). Continued migration places hundreds of homes in Troutdale at risk. This is another topic that the city of Troutdale could investigate further.

Earthquake Liquefaction

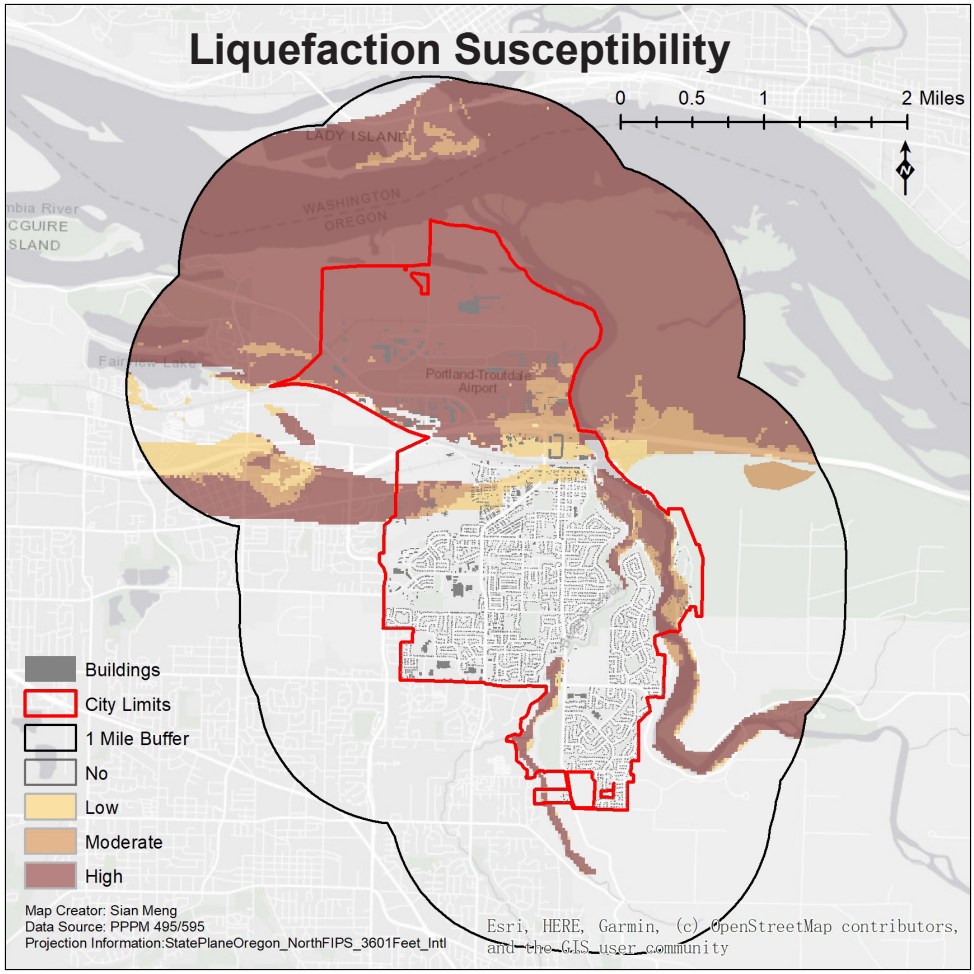
FIG. 4-1
Earthquake liquefaction
United States Geological Survey

OVERVIEW

Liquefaction as a result of an earthquake occurs when loosely packed, water-logged sediment at or near the ground surface loses strength (USGS, 2021a). Liquefaction susceptibility is the degree to which areas are vulnerable to earthquake liquefaction, with the assumption the ground is fully saturated. Liquefaction susceptibility for the city of Troutdale was derived from Oregon Statewide Geohazards Viewer, which adopted the FEMA HAZUS-MH MR4 Earthquake Model that assigns susceptibility classes based on geology. The liquefaction susceptibility overview map classifies Oregon into the following susceptibility zones: 53.7% no, 2.5% low, 4% moderate, and 39.8% high (Figure 4-2). In contrast to the previous three hazard types, almost 40% of the study area is divided into high susceptibility class, which is mainly concentrated on the north side of Troutdale, near the Columbia River, and along the Sandy River and Halsey Street.

FIG. 4-2

Overall liquefaction susceptibility map



COMMUNITY ASSETS

Economic Assets

The economic assets within Troutdale city limits include residential and commercial buildings, major employers, and tourist destinations. Figure 4-3 shows that many major employers and tourist destinations are in high exposure areas, especially in the northern part of town closer to the Columbia River. Table 4-1 displays that almost half of the commercial buildings are in the moderate to high susceptibility area, accounting for an estimated economic value of $2.13 billion. Additionally, the economic value of residential buildings in moderate to high liquefaction susceptibility areas is about $46.3 million, although most of the residential buildings are located in low or no susceptibility areas.

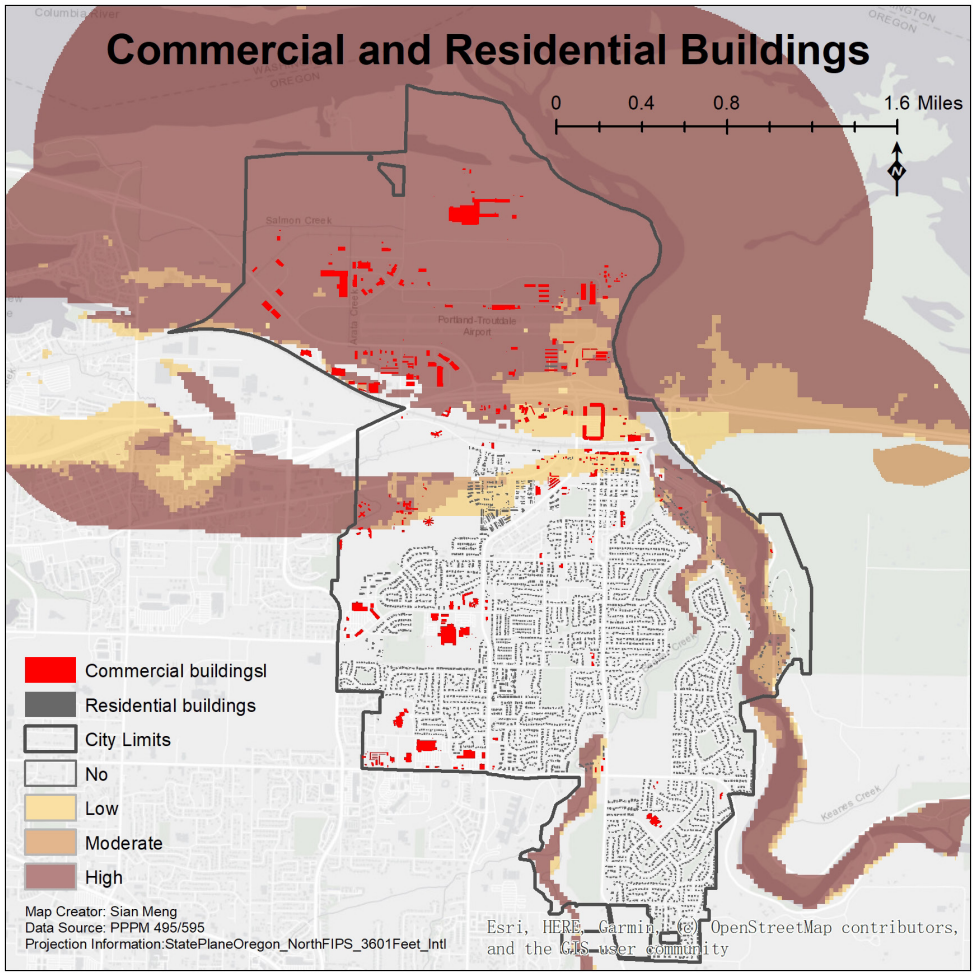


FIG. 4-3
Commercial and residential buildings in troutdale

TABLE 4-1

Economic Asset Summary

Commercial Buildings	
Hazard Level	**Estimated Economic Value**
Low Susceptibility	$153,346,150
Moderate Susceptibility	$274,507,470
High Susceptibility	$1,864,760,570
Residential Buildings	
Hazard Level	**Estimated Economic Value**
Low Susceptibility	$714,041,340
Moderate Susceptibility	$18,844,110
High Susceptibility	$27,514,940
Major Employers	
Hazard Level	**Estimated Economic Value**
Low Susceptibility	$7,839,050
High Susceptibility	$255,758,290
Tourists Destinations	
Hazard Level	**Estimated Economic Value**
High Susceptibility	$26,665,190

Critical Infrastructure

Most emergency and health-related facilities are in no or low liquefaction susceptibility areas, with few possible emergency shelters and health-related facilities in northern Troutdale subject to high-susceptibility level liquefaction. Following the overall liquefaction susceptibility distribution, Figure 4-5 and 4-6 show the transportation and utility infrastructure in northern Troutdale. Along the Sandy River and Halsey St. There are moderate to high susceptibility areas, including 23 bus stops, 14 bridges, three sewer/pump stations, one electric substation, and extensive line-type facilities (Table 4-2).

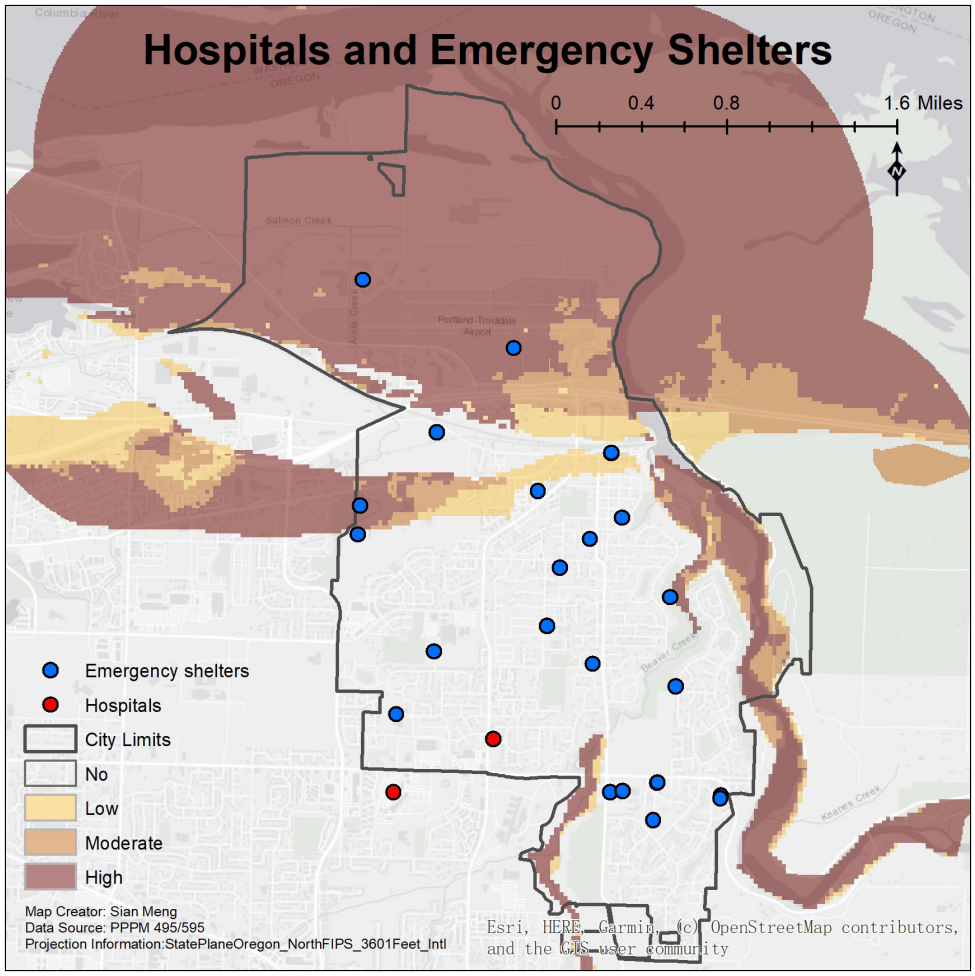
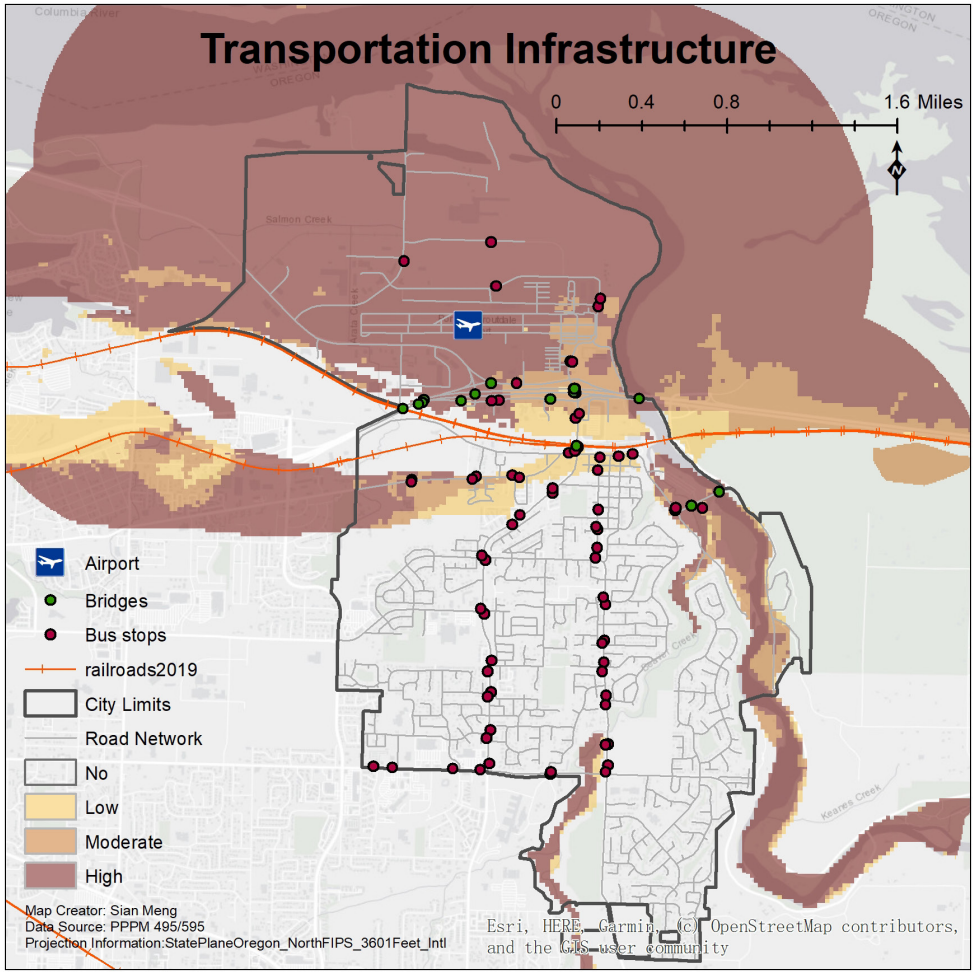


FIG. 4-4
Emergency and health-related infrastructure map

FIG. 4-5

Transportation infrastructure map



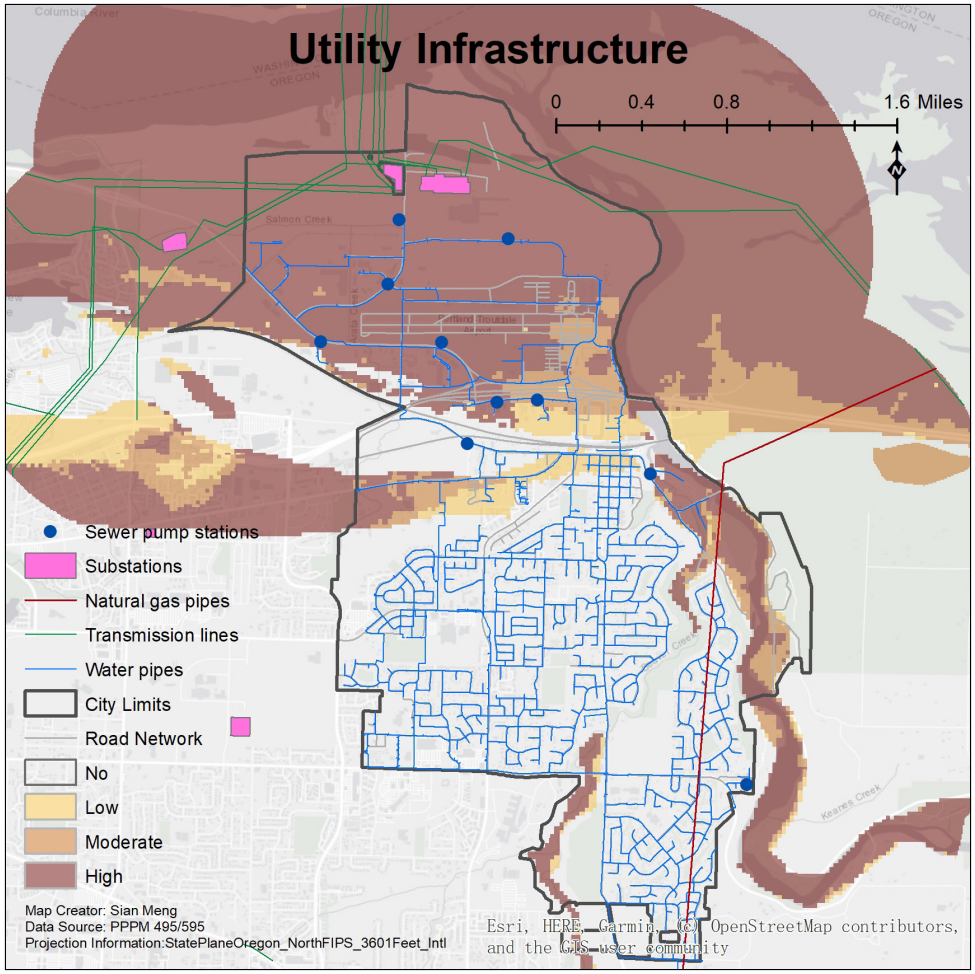


FIG. 4-6
Utility infrastructure map

TABLE 4-2

Critical Infrastructure Summary

Childcare Facilities			
Hazard Level	**Estimated Economic Value**	**Square Footage**	**Count**
No Susceptibility	$13,001,280	73,073	2
Nursing Homes			
Hazard Level	Estimated Economic Value	Square Footage	Count
No Susceptibility	$ 4,221,850	30,750	1
Childcare Facilities			
Hazard Level	**Estimated Economic Value**	**Square Footage**	**Count**
No Susceptibility	$ 13,793,320	N/A	2
Childcare Facilities			
Hazard Level	Estimated Economic Value	Square Footage	Count
No Susceptibility	$ 8,870,140	N/A	5
Childcare Facilities			
Hazard Level	Estimated Economic Value	Square Footage	Count
No Susceptibility	$ 63,787,940	214,204	4
High Susceptibility	$ 9,179,180	3,630	1
Childcare Facilities			
Hazard Level	Estimated Economic Value	Square Footage	Count
No Susceptibility	$ 4,337,420	15,424	8
Low Susceptibility	N/A	N/A	72
Low Susceptibility	$ 193,280	1,080	2
High Susceptibility	$ 19,905,220	4,080	2

Critical Facilities

Results show that most of the critical facilities exist in areas not susceptible to liquefaction, such as childcare, nursing homes, mobile home parks and places of worship. By contrast, several cultural places and one public school are located in the moderate to high susceptibility area (Figure 4-7).

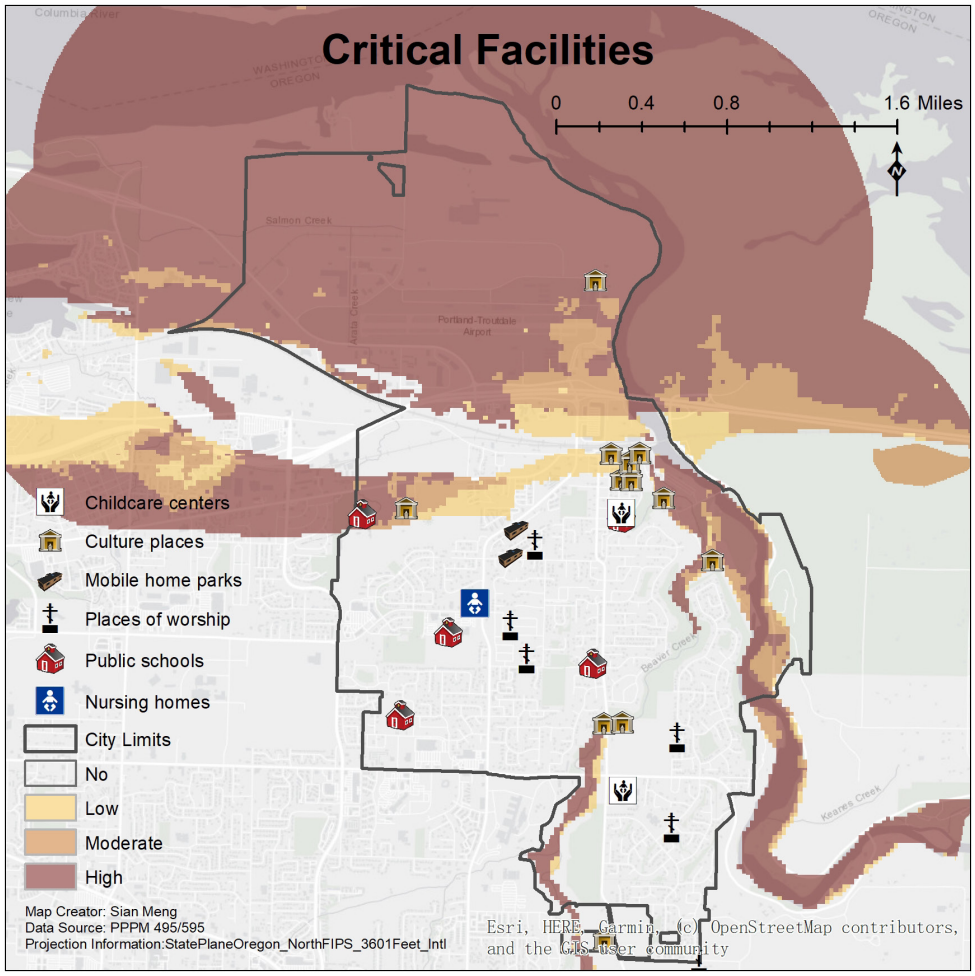


FIG. 4-7
Critical facilities map

Natural Resources

Within the city limit, two parks and one greenway are in high susceptibility areas, with a total of 8.7 acres. According to Figure 4-8, Glen Otto is surrounded by high susceptibility areas despite the center of the park being classfied as low to no susceptibility. Table 4-3 summarizes the area and number of nature resources in high susceptibility areas. Additionally, Troutdale may consider the ecological functions of natural resources when determining priority. Greenways may serve important ecological functions, such as flood control or habitat for sensitive plants and animals, that may compound with simultaneously occurring hazards. Lastly, agricultural lot property owners could be notified of the threat level that is posed to their properties and be encouraged to make plans accordingly.

FIG. 4-8

Natural resources map

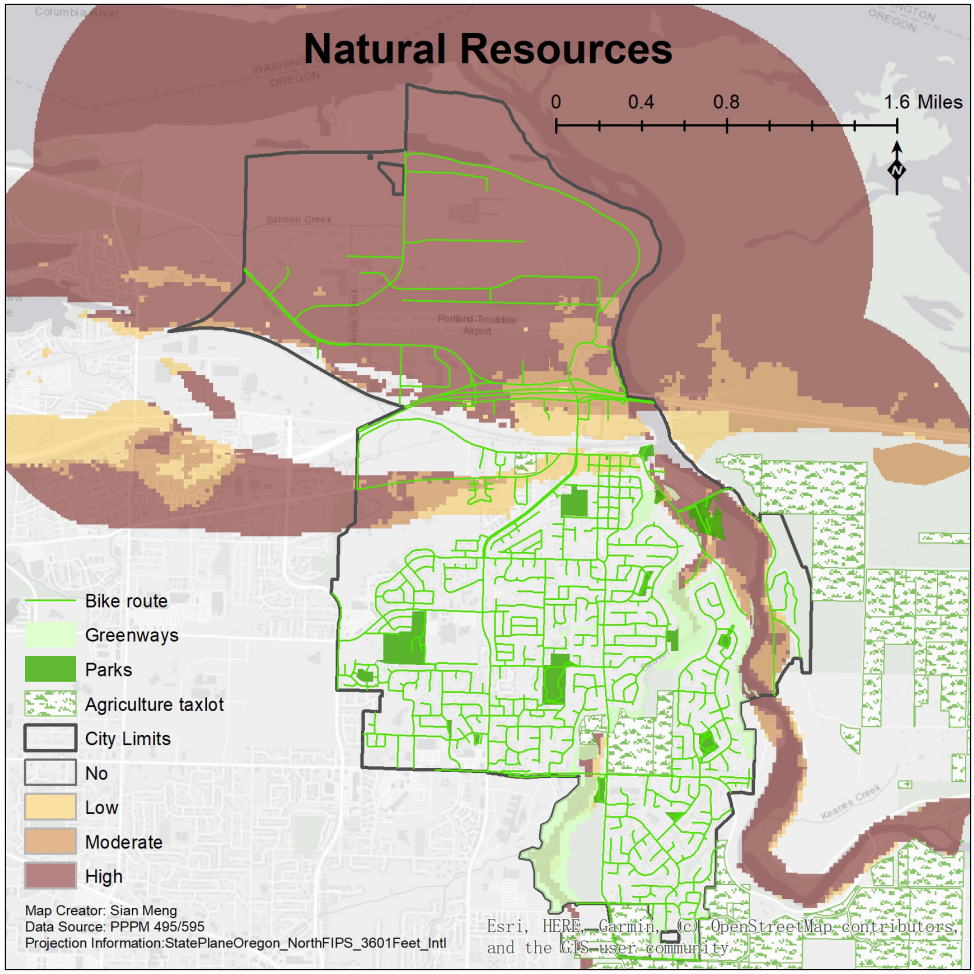


TABLE 4-3

Natural Resources Summary

City Parks			
Hazard Level	**Estimated Economic Value**	**Square Footage**	**Count**
High Susceptibility	N/A	322,344	2
Greenways			
Hazard Level	**Estimated Economic Value**	**Square Footage**	**Count**
Low Susceptibility	N/A	588,060	3
High Susceptibility	N/A	56,628	1

VULNERABLE POPULATIONS

In our examination of social vulnerability and liquefaction hazard, we identified four census block groups as the highest priority. Across all indicators (elderly population 65 and over, population under 18 years, differently-abled, and below the poverty line), the highest number of people are located on the east side of Troutdale. Our analysis does not show any of these populations living in low, moderate, or high liquefaction hazards in other block groups. The block group with the highest vulnerable population across all vulnerable populations is the on the east side of the Sandy River, which also includes area outside of Troutdale(Figure 4-9). The next three block groups are on the west of the Sandy River with varying numbers of vulnerable populations.

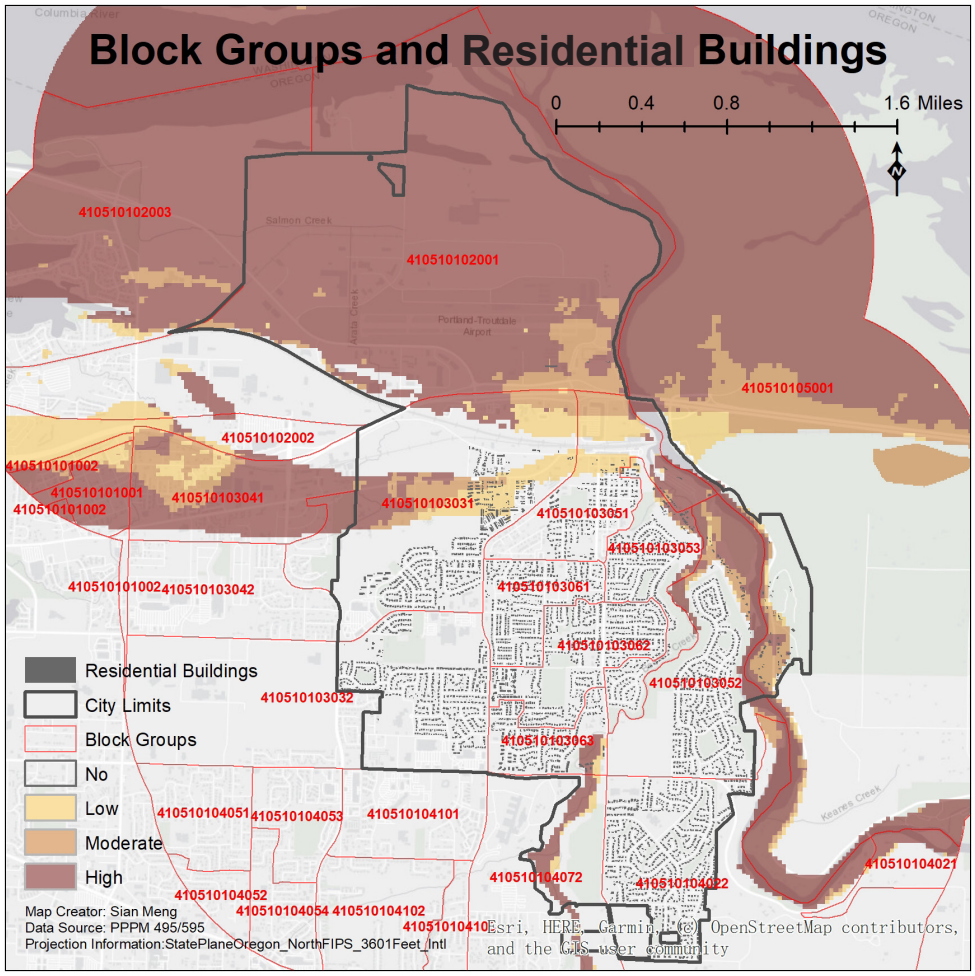


FIG. 4-9
Census block groups map

DISCUSSION AND RECOMMENDATIONS

Earthquake liquefaction poses the highest threat to resources located in the northern part of Troutdale. These include major area employers, commercial and industrial buildings and infrastructure, and critical facilities such as a school, materials laboratory, and Edgefield, formerly known as the Multnomah County Poor Farm. Commercial buildings under threat are worth $1.8 billion in economic assets. The airport and many of the City's major employers are separated from the City's health services and emergency response facilities by a series of bridges on the north side of the city. Troutdale may consider increasing the connectivity between the northern part and the rest of the city. Furthermore, many of the utilities are located in the northern area of Troutdale, therefore diversifying location of utilities could be considered.

Along the Sandy River and Beaver Creek, greenways are listed as high threat to liquefaction as well as vulnerable populations that reside in residential areas near such waterways. One of Troutdale's more popular parks, Glenn Otto Park, is located in a high threat to liquefaction area. A liquefaction event would cause a significant economic blow, both locally and regionally, as well as potentially impacting a high number of people recreating in the high susceptibility area during hours of operation. Additionally, Troutdale may consider the ecological functions of natural resources when determining priority. Greenways may serve important ecological functions, such as flood control or habitat for sensitive plants and animals, that may compound with simultaneously occurring hazards. Agricultural lot property owners could be notified of the susceptibility level that is posed to their properties and be encouraged to make plans accordingly.

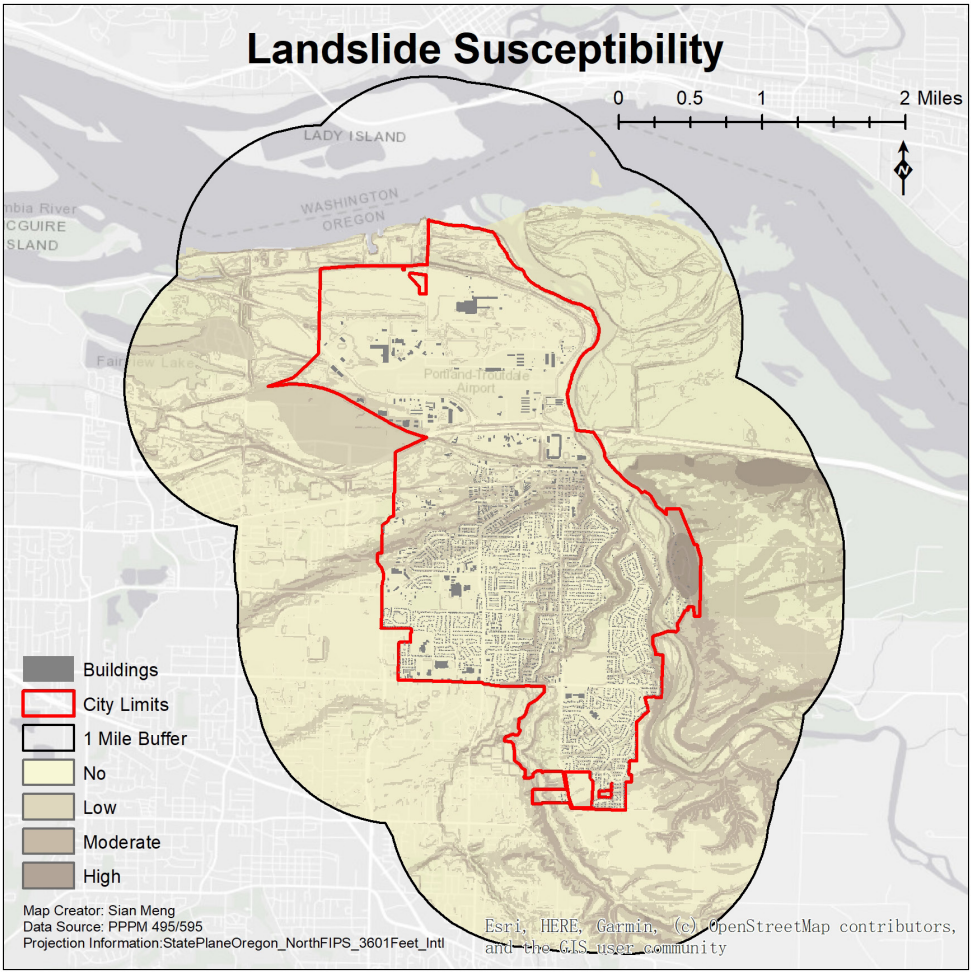
Landslides

FIG. 5-1
Landslide
Hironori Asakawa, Kyodo News

OVERVIEW

A landslide is defined as the downslope movement of rock, soil, or related debris (USGS, 2021b). Landslide susceptibility for the city of Troutdale was derived from Statewide Landslide Information Database for Oregon (SLIDO), which combined generalized geology and landslide inventory to determine landslide area. The landslide susceptibility overview map classifies Troutdale and the buffer area into the following susceptibility zones: 60% no, 30% low, 9% moderate, and 1% high (Figure 5-1).

FIG. 5-2
Overall landslide susceptibility map



The highest susceptibility area is on the eastern extremity of Troutdale's city limits, which recorded a historic landslide and is the only high-susceptibility area within the city boundary. This area's high susceptibility status is due to the disturbed soils that resulted from the historic landslide, as well as the steep slopes of the region. Additionally, the majority of the region to the east of this high susceptibiltiy area is higher in average susceptibility level than the current Troutdale city limit area, which could be analyzed in future urban growth boundary expansion or urban reserve planning. The second area worth noting due to its higher-than-average susceptibility is the area directly adjacent to the Sandy River and Beaver Creek streambeds. These areas are typically in the moderate susceptibility category largely due to the high presence of water that erodes the soil base, as well as the higher slopes. These areas will be critical in planning for floodplain management and flood hazard planning as flood events can increase the susceptibility for landslides compared to normal circumstances. The third area to highlight in Troutdale is the bluff that runs from west-southwest to east-northeast south of Interstate-84. This bluff has more low-susceptibility and some moderate-susceptibiltiy areas that are largely due to the slopes. While not a priority compared to the previous two zones, it could still be considered for landslide planning moving forward.

COMMUNITY ASSETS

Economic Assets

An analysis of the economic assets demonstrates landslide susceptibility threatens a limited percentage of economic assets. Table 5-1 summarizes the economic asset analysis, with three commercial buildings out of 398 in the moderate-susceptibility category and none in the high-risk category. These three buildings account for little over $5 million in economic value. There are more residential buildings in the moderate and high-susceptibility categories, with 22 R-1 buildings in the high-susceptibility area of the historic landslide. These 22 buildings amount to nearly $4 million in value, and the 119 buildings within the moderate susceptibility category amount to over $52 million. This combined $56 million is a significant number and could be prioritized over threatened commercial buildings.

TABLE 5-1

Economic Assets and Landslide Susceptibility

Hazard Level	Employers	Tourist Destinations	Commercial Buildings			R-1 Buildings		
			Count	Square Footage	Value	Count	Square Footage	Value
No Susceptibility	5	5	333	8,842,648	2,563,011,660	3289	8,433,324	1,684,642,410
Low Susceptibility	1	1	62	968,319	331,315,090	1367	15,525,991	1,674,445,820
Moderate Susceptibility	0	0	3	15,171	5,106,430	119	448,063	52,408,260
High Susceptibility	0	0	0	0	0	22	21,030	3,971,020

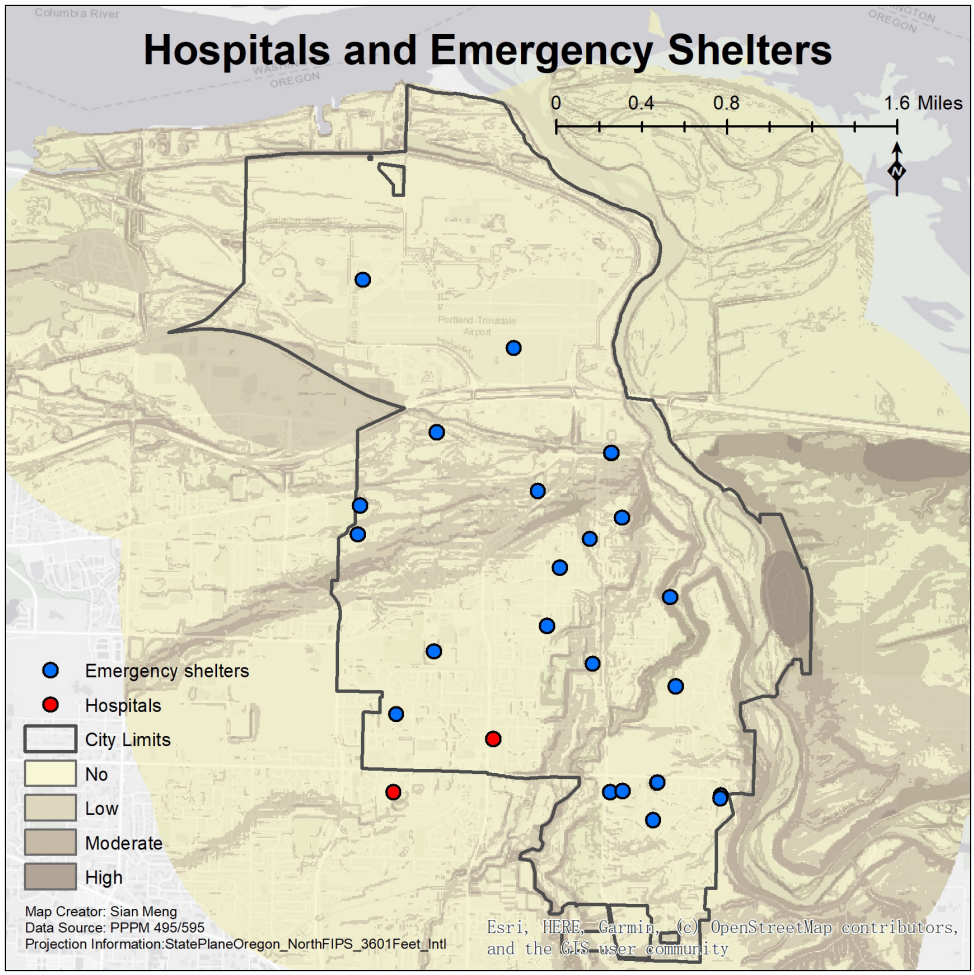
Critical Infrastructure

The majority of critical infrastructure is located in no or low landslide susceptibility areas, while utility infrastructure is at the most relative probability of landslide disruption (Figure 5-3). Table 5-2 shows that around 3 miles of water/sewer pipes, 0.63 miles of transmission lines, and 0.7 miles of natural gas line run through the moderate susceptibility area.

Even though only a small proportion of utilities are at risk compared to the overall system, a landslide may shut down part or the entirety of the local electricity or gas lines that may also have regional connections. Additionally, 3% of the road network is in the moderate susceptibility area, and 1% of the road network is in the high susceptibility area.

FIG. 5-3-1

Critical infrastructure map



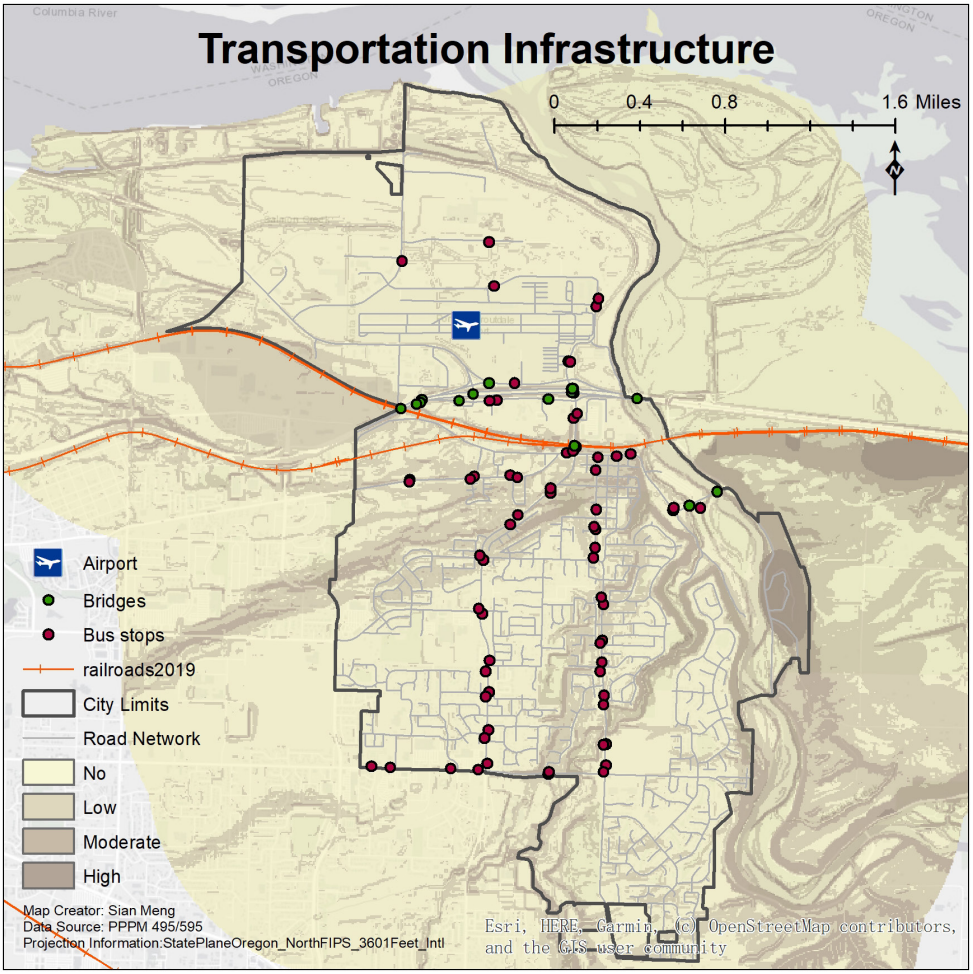


FIG. 5-3-2
Transportation infrastructure map

FIG. 5-3-3

Utility infrastructure map

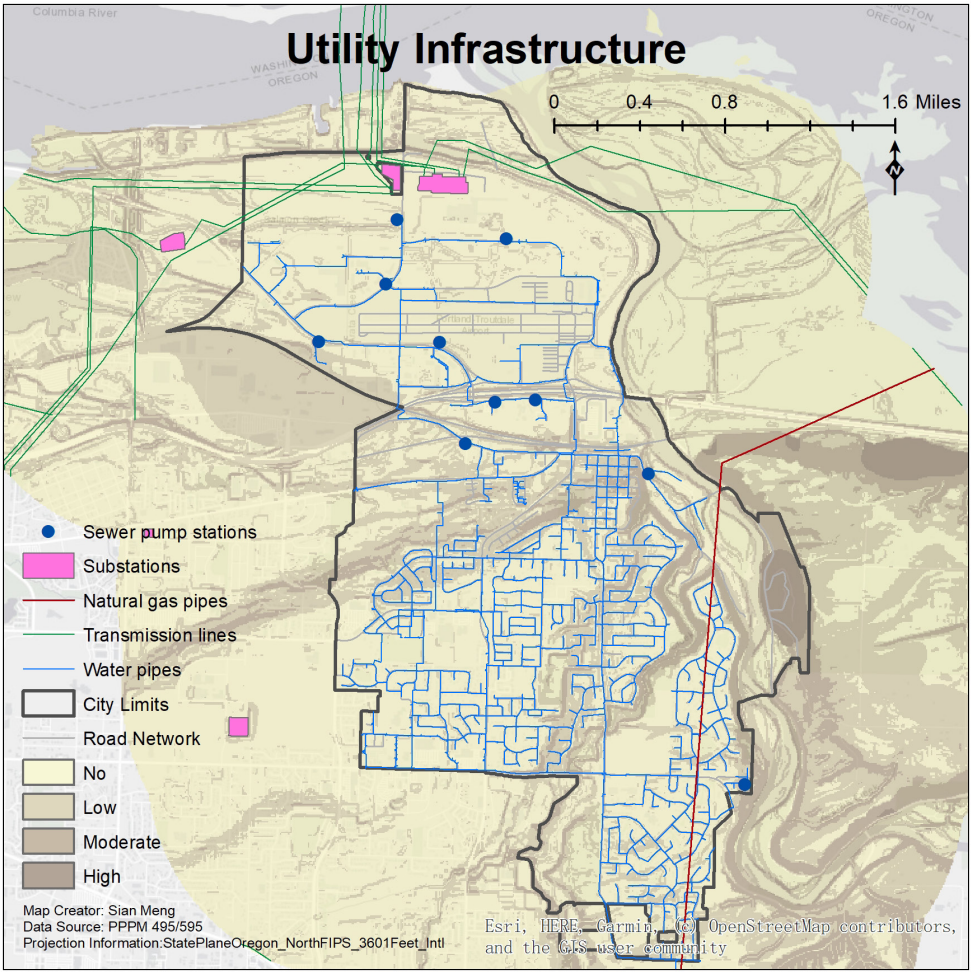


TABLE 5-2

Critical Infrastructure and Landslide Susceptibility

Hazard Level	Pump/ Sewer stations	Water pipes (miles)	Sewer pipes (miles)	Transmission lines (miles)	Natural gas line (miles)	Substation
No Susceptibility	6	49.78	41.74	18.21	2.79	1
Low Susceptibility	4	16.27	12.48	6.32	0.94	0
Moderate Susceptibility	0	1.29	1.81	0.63	0.7	0
High Susceptibility	0	0	0	0	0.01	0

Community Facilities

The analysis of community facilities shows that most exist in no or low susceptibility areas, and no community facilities are in high susceptibility areas. Only two residential buildings with historic status are in the moderate susceptibility category, the City could engage in conversations with the property owners of these buildings regarding landslide risk (Table 5-3).

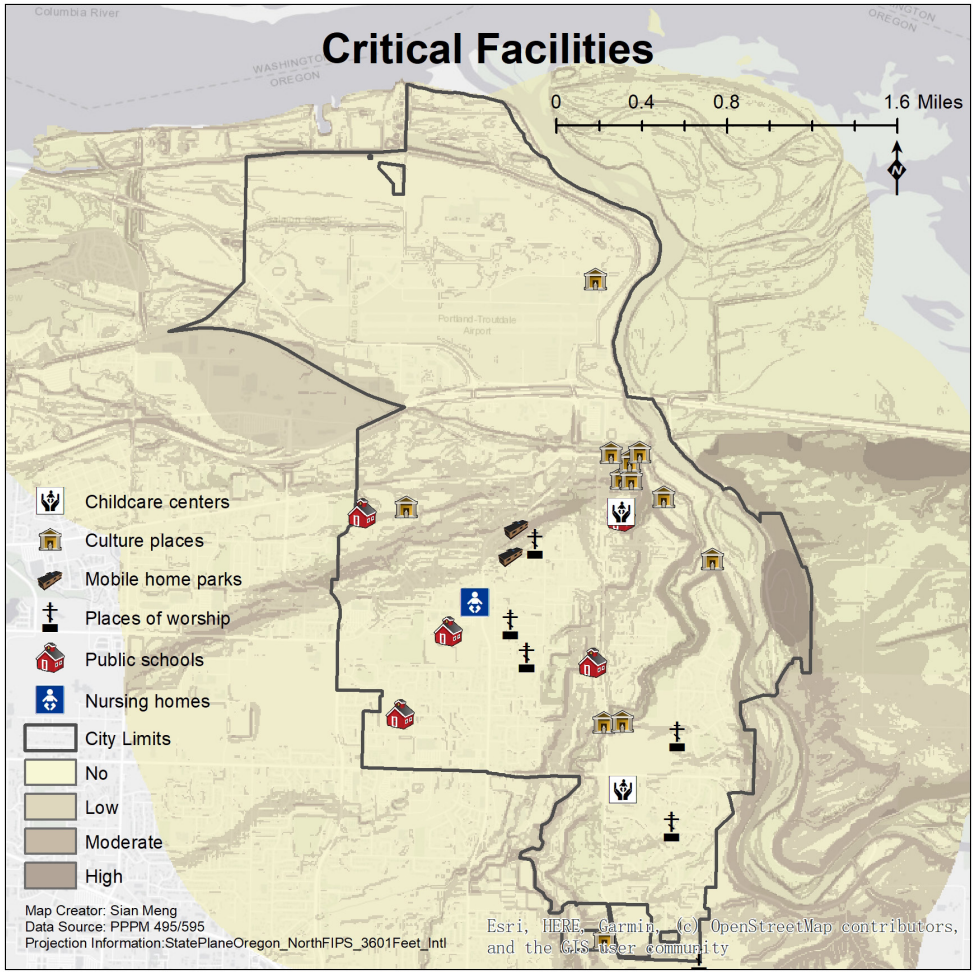
TABLE 5-3

Community Facilities and Landslide Susceptibility

Hazard Level	Historical Cultural Places	Childcare Facilities	Nursing Home	Mobile Home Park	Place of Worship	Public School
No Susceptibility	5	2	1	0	7	4
Low Susceptibility	12	0	0	2	2	1
Moderate Susceptibility	2	0	0	0	0	0
High Susceptibility	0	0	0	0	0	0

FIG. 5-4

Community facilities map



Natural Resources

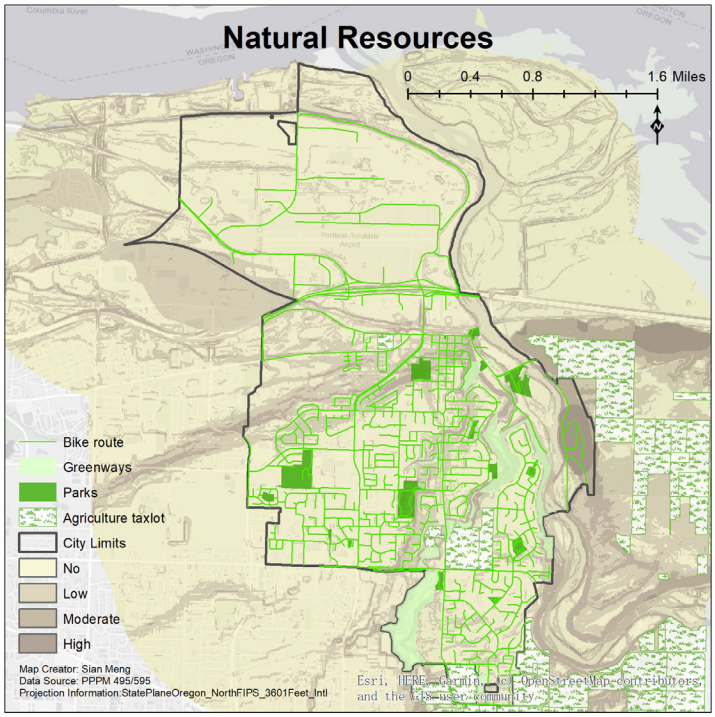


FIG. 5-5
Natural resources map

TABLE 5-4

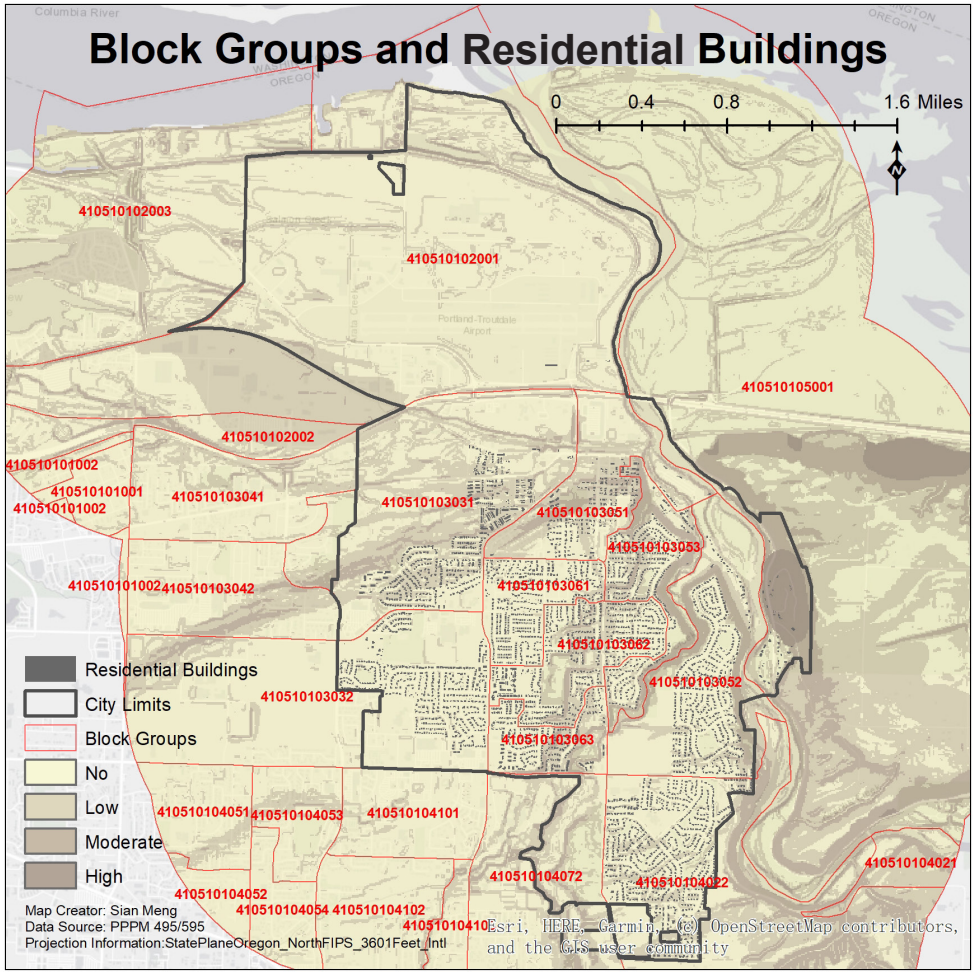
Natural Resources and Landslide Susceptibility

Hazard Level	Percentage of Parks and Greenways' Area
No Susceptibility	63%
Low Susceptibility	25%
Moderate Susceptibility	12%
High Susceptibility	0%

VULNERABLE POPULATIONS

Almost no vulnerable populations live in the high landslide susceptibility area, except for the block group on the east side of the Sandy River. This block consists of a high proportion of youth. In addition some properties are located where the historic landslide occurred. Block groups with more vulnerable people in moderate landslide susceptibility areas are east of Beaver Creek, as many properties were built along the Creek (Figure 5-4).

FIG. 5-6
The distribution of vulnerable communities



DISCUSSION

The vast majority of the City is in no or low-susceptibility areas. Particularly large sections of the City in the northern, southwestern, and southern regions lack any significant risk. The primary areas of risk are located in the historical landslide area on the eastern extreme of the city boundaries, and the slopes directly adjacent to the Sandy River and Beaver Creek. Landslide susceptibility can be addressed in policies and targeted preparation and prevention efforts in these regions, and tactical deployment of funds and staff to undertake these efforts on a small scale can mitigate the impacts of this hazard. Specifically, most high landslide susceptibility areas are parks or other natural resources. Parks and maintenance staff could monitor these areas to ensure they remain safe for recreation opportunities.

Emergency Response

OVERVIEW

Students conducted a network service area analysis to evaluate the effectiveness of emergency response and shelters (e.g., church, city hall, and school). The student research team considered the potential impacts of hazards on public infrastructure and how these impacts may decrease response time and service capacity.

NETWORK ANALYSIS

Figure 6-1 shows the 1-mile catchment area (light color) and 3-mile catchment area (dark color) of hospitals, fire stations, and police offices. The recommended fire response time by the National Fire Protection Association is 9 minutes 20 seconds. Using 9 minutes as a benchmark, the response time in Troutdale would likely be below 9 minutes as Troutdale is a small community.

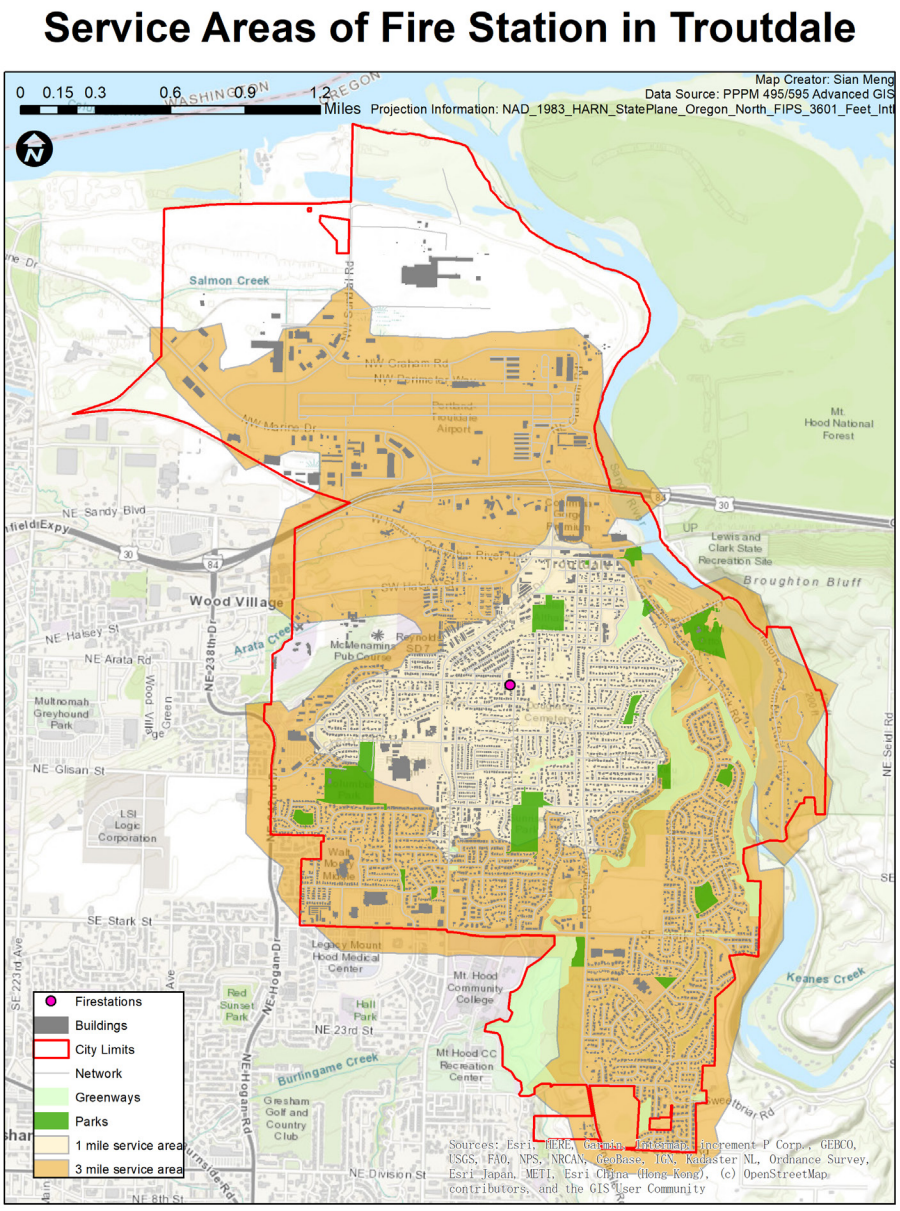
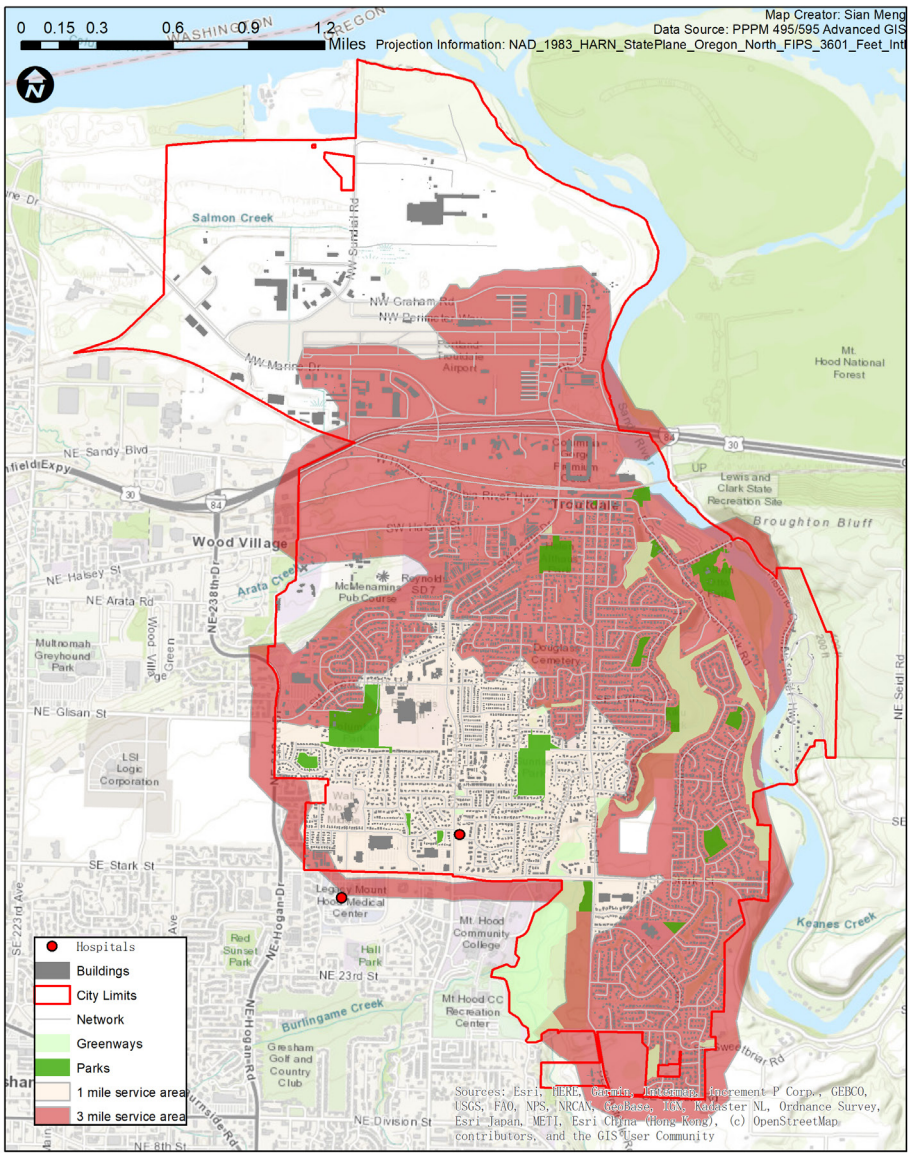


FIG. 6-1-1

1 and 3-mile catchment areas by network distance

FIG. 6-1-2

1 and 3-mile catchment areas by network distance



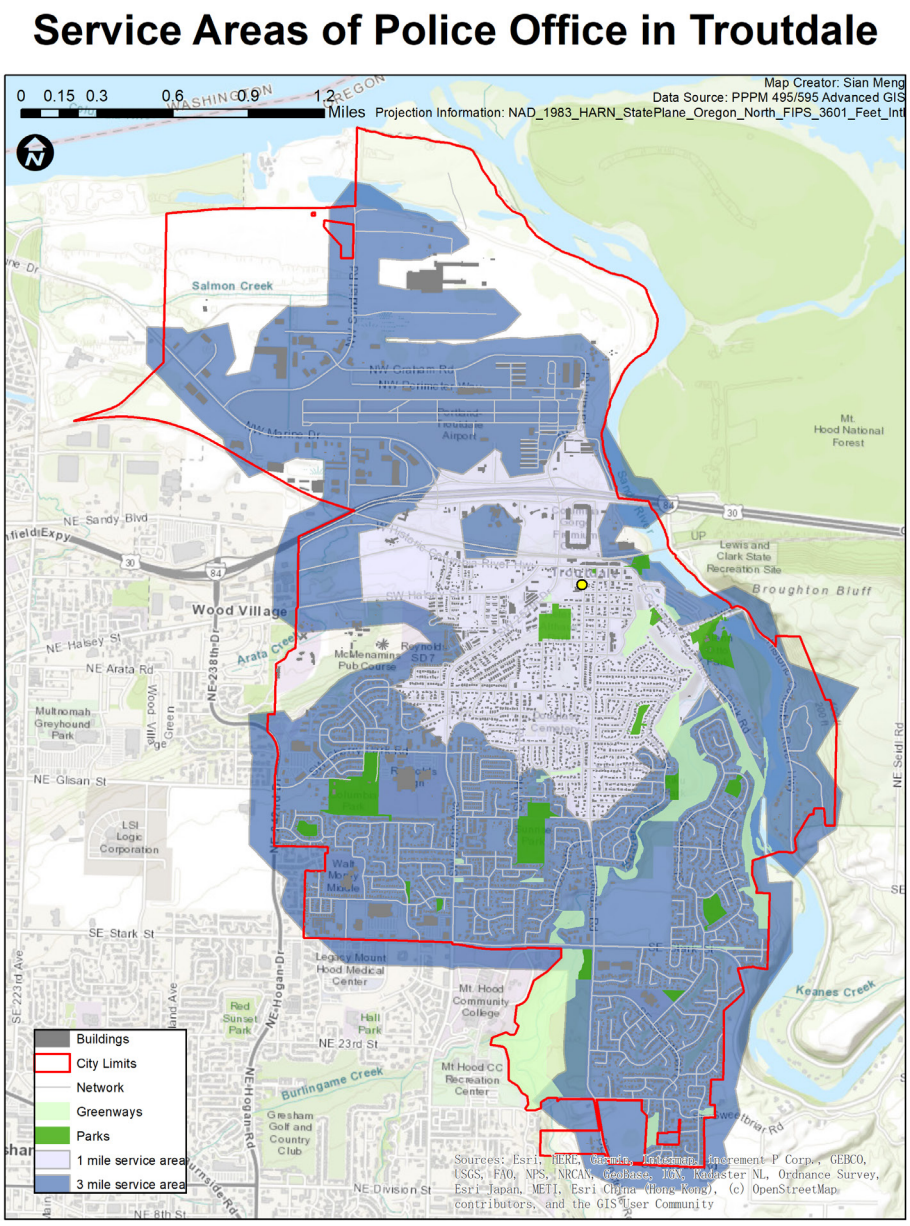


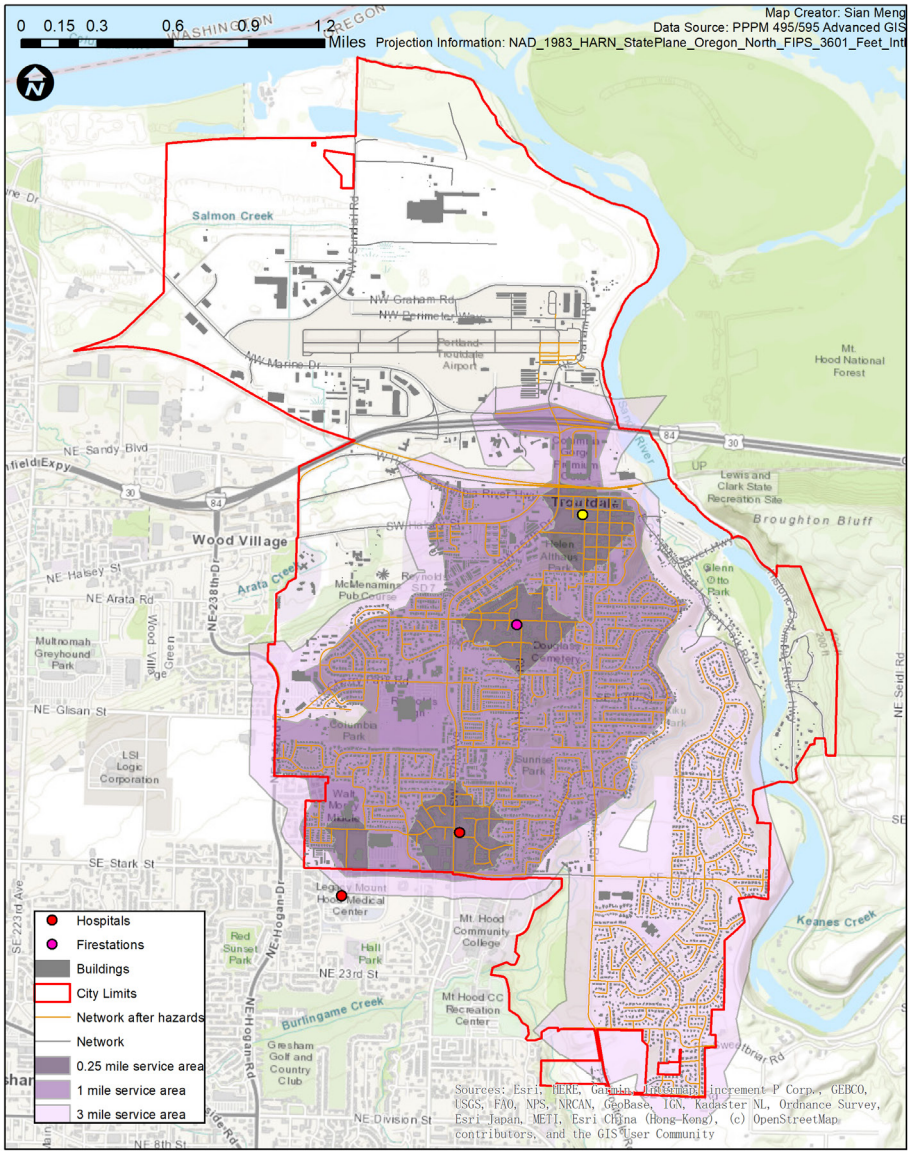
FIG. 6-1-3
1 and 3-mile catchment areas by network distance

However, if a hazard like a liquefaction landslide occurs, some road facilities may not be available. In Figure 6-2, we clipped road networks in these high susceptibility areas. Disconnection of roads in yellow circles may prevent emergency response from reaching the north and east part of the City by driving. Additionally, we checked emergency shelters - city halls, schools, gyms, and so on - in low or no threat areas; there are no available shelters in the north and east in the event of a hazard or multi-hazard. Therefore, if the roads around I-84 and bridges on the Sandy River are unavailable following a hazard, we suggest Troutdale plan alternative ways to access the north and east parts of the city, such as implementing emergency routes in low susceptibility areas.

FIG. 6-2-1

0.25, 1, and 3-mile catchment areas by network distance

Service Areas of Emergency Responses in Troutdale



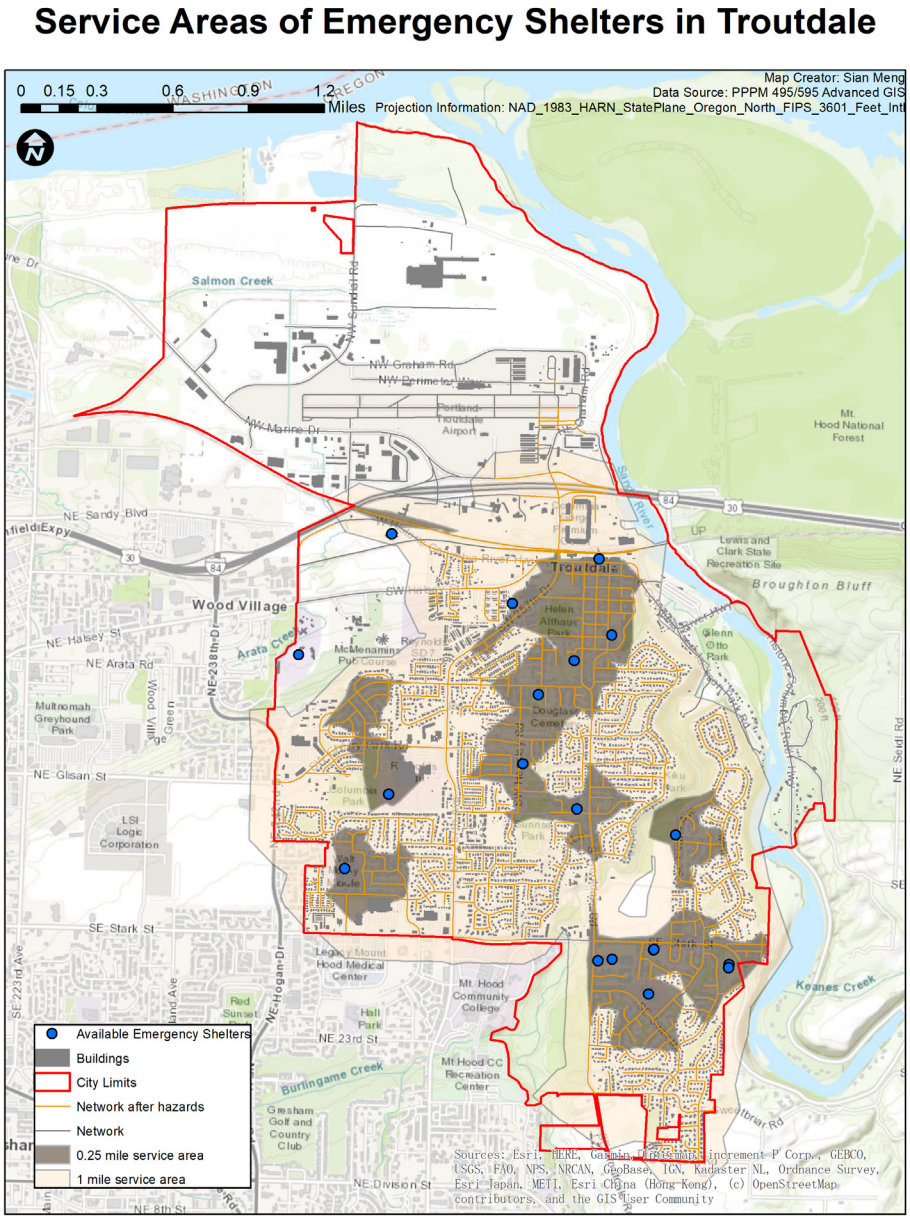


FIG. 6-2-2

0.25, 1, and 3-mile catchment areas by network distance

Conclusion

KEY FINDINGS

Figure 7-1 is the overlay map showing multi-hazard susceptibility. First, high exposure to all hazards is minimal. Second, the highest susceptibility area is largely concentrated near waterways, including the Columbia River, Sandy River, and Beaver Creek. Third, commercial buildings in the north are susceptible to less overall exposure to all hazards, even though these buildings exist in high-susceptibility liquefaction areas. Additionally, for each hazard type, the key findings are summarized in Table 7-1.

FIG. 7-1
Multi-Hazard Susceptibility Map

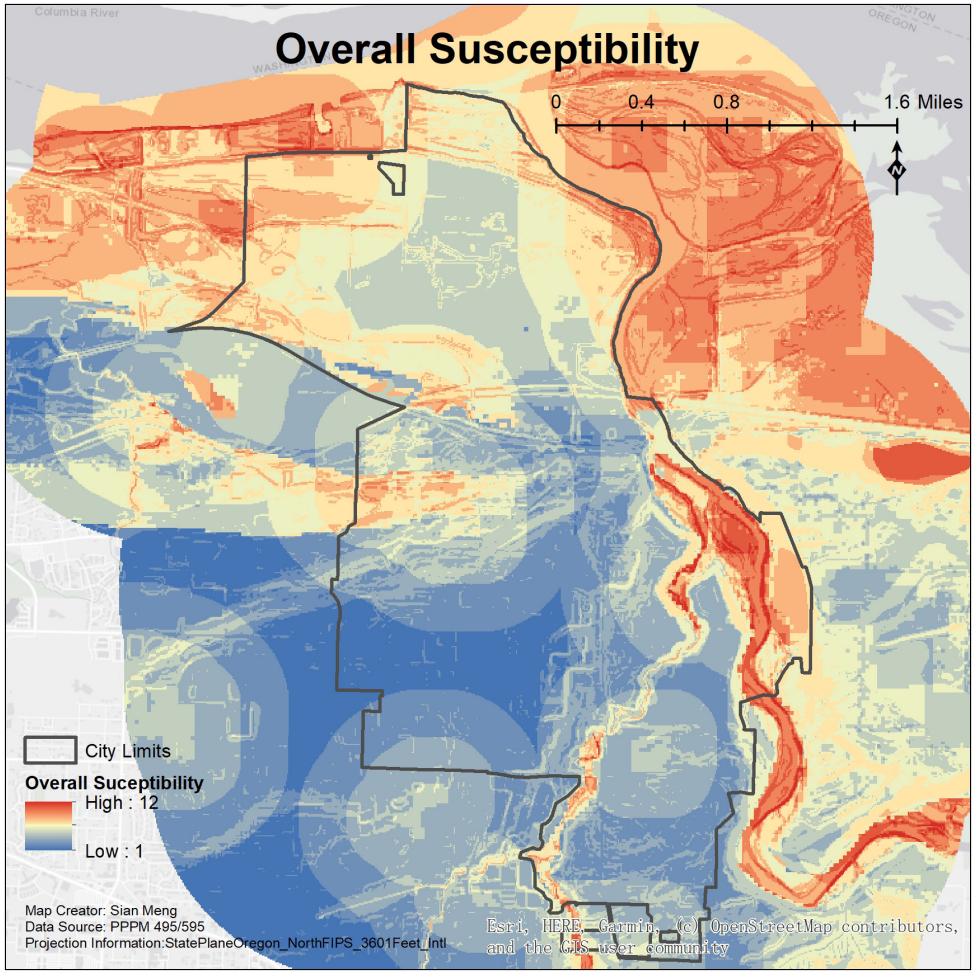


TABLE 7-1

Key Findings for Each Hazard Type

Summary of Analysis
Flood Summary
• The majority of high susceptibility level is on the east of Sandy River and north of Columbia River • Organize public awareness workshops
• Major employers are located in 500-year flood zones
• Most of the pre-1970 buildings are residential homes and sit in 100-year flood risk • Parts of transmission lines, sewer pipes, water pipes, and natural gas lines possibly are at risk
• Glenn Otto Community Park is intersected with floodways
• Vulnerable Populations are largely concentrated on the west side of town, where there is low flood susceptibility
Wildfire Summary
• Multiple tourist destinations are in high and moderate burn susceptibility areas • Agricultural land is especially vulnerable, with $2 million worth in high burn susceptibility areas
• Childcare centers, mobile home parks, and places of worship are the most vulnerable, located in moderate burn susceptibility areas
Liquefaction Summary
• $1.8 billion of Commercial buildings are in high liquefaction susceptibility areas
• The majority of Commercial Buildings are in high liquefaction susceptibility areas
• Arata Creek School, USACE Materials Laboratory, and Multnomah County Poor Farm are high-risk
• Three of Troutdale's parks are in high liquefaction susceptibility areas
• Vulnerable populations are located along the sandy river, where there is high liquefaction susceptibility
Landslide Summary
• The majority of Troutdale is in low to no landslide susceptibility zones
• Residential buildings with almost $4 million in economic value are in high landslide susceptibility areas
• Childcare Centers, Mobile Home Parks, and Places of Worship are the most vulnerable, located in moderate burn susceptibility areas
• Most utility infrastructure is in low to no landslide susceptibility areas, which supports resilience systems

RECOMMENDATIONS

Student research teams provide recommendations on hazard response to the city of Troutdale in terms of Prevention and Preparation (Figure 7-2).

FIG. 7-2
4 Phases of A Disaster Response

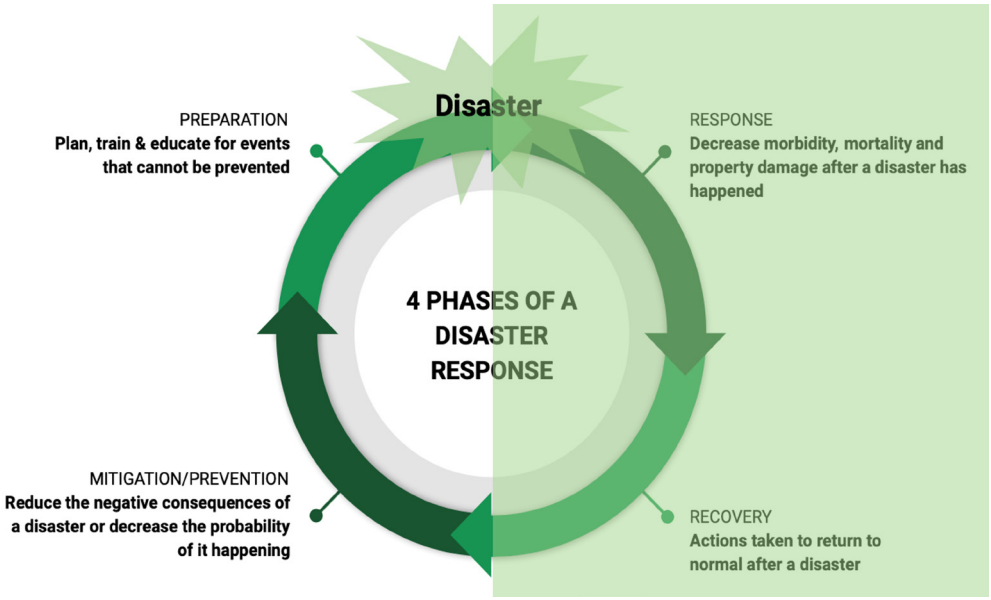


TABLE 7-2

Summary of Recommendations

Suggestions and Recommendations
Preparation Strategies
• Increase awareness of high-threat/high-vulnerability residents • Encourage pocket response plans, back-up supplies, awareness of evacuation routes, and personal evacuation plans • Organize public awareness workshops
• Signage on hazards and evacuation routes at tourist destinations
• Identify and coordinate city-level emergency response partners
• Consider non-traditional partners in emergency management – economic development practitioners, heritage resource organizations, community organizations
• Identify alternative evacuation routes when I-84 and bridges on Sandy River are impacted by hazards
• Locate funding to retrofit transportation, utility, and emergency response infrastructure
Mitigation/Prevention Strategies
• Utilize land use codes to limit future development in high-threat areas, especially for populations at high vulnerability
• Partner with city or county level organizations to provide housing options or shelter locations away from high-risk hazard areas, including clean air
• Identify funding for retrofitting of transportation, utility, and emergency infrastructure
• Identify funding for retrofitting of both private and public property, utilizing the inventories from this project as a starting point
• Provide support to agricultural property owners/natural resources abutting residential areas to create defensible spaces (fuel reduction)
• Conduct additional research on other vulnerable populations identified by the city and not addressed in this study

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Appendix A

Flooding Final Report

Flood Hazard Probability

Class Project Final Report for PPPM 495/595 Advanced GIS

Rachel Peterson, Grace Hardy, James Conway, Lydia Caudill

Spring Term, June 2021

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BACKGROUND

Global climate change is a reality and has increasing negative impacts across the globe and in Oregon. The City of Troutdale is no exception to natural hazards that are accentuated by climate change. Every year increased frequency of natural hazards occurs, and this presents many challenges to states and local government. Troutdale, like many communities in Oregon, is facing increased exposure and vulnerability to hazards like floods. The source of flooding is an excess of water onto dry land that become submerged in water. Heavy rain fall which is ever present in the Pacific Northwest result in overflow of streams, lakes, and rivers resulting in millions of dollars in economic, infrastructure and private loss. Hazard mitigation, planning, preparedness, and public policy are tools for local government leaders to combat the challenge of increasing hazards, like flooding. Probability assessment and vulnerability analysis are critical in Troutdale's effort to be efficient and effective in their preparedness and response to flooding.

PURPOSE

This report's focus is to gather data, create maps and preform professional spatial distribution analysis to find the probability of flooding and assess the impacts on the economy, infrastructure, critical facilities, natural resources, and community members of Troutdale. The findings of this report will aid mitigation planning. Using the United States Geological Survey (USGS) and the National Risk Index for Natural Hazards (NRI) a framework for flood probability assessment was formed. The key feature of the NRI are inputs. These inputs are flooding and community assets, that include physical structures and the human element and demographics of community. Community assets were inventoried, and data was utilized to estimate possible property value loss while examining the possibility and location of vulnerable populations in relation to the hazard area. The vulnerable populations observed were peoples over 65, under 18, disabled and below the national poverty level. This report goes more in depth of the methodology and the analysis process while summarizing the findings for each community assets and concludes with a discussion of the relationship between the environmental hazard of flooding and Troutdale's residents' quality of life.

2. METHODOLOGY

2.1 Study Area

This report's study area began with the City of Troutdale's city limits. However, initial conversations with Troutdale planners led us to reconsider the area of analysis upon which we would focus. It was brought to our attention that the unincorporated area to east of the city limits is experiencing growth and expansion. While not formally within the boundaries of the city, this population is nonetheless

dependent on the resources provided by Troutdale. With this additional information, it was decided that the research analysis should include a one-mile buffer area around the city limits.

Analysis of social vulnerability required further consideration of the study area. U.S. Census data was used to gather population information, predominantly using Census Block Groups. However, block groups do not perfectly align with city limits, which necessitated an additional decision on which block groups would best represent the population within Troutdale. The most northern area of Troutdale was not included as it predominantly is an industrial area, and its block group extends to the west, primarily representing non-Troutdale residents. The lower-right and the lower-left block groups were included even though their boundaries extended beyond the city limits because, as demonstrated by the tax lots, most of the residential area still lie within the city limits. Finally, the large block group that extended beyond the city limits to the east was also included. This was due both to the fact that most of the residents in that block group still live within the city limits and because it is identified as an area whose population is dependent on Troutdale.

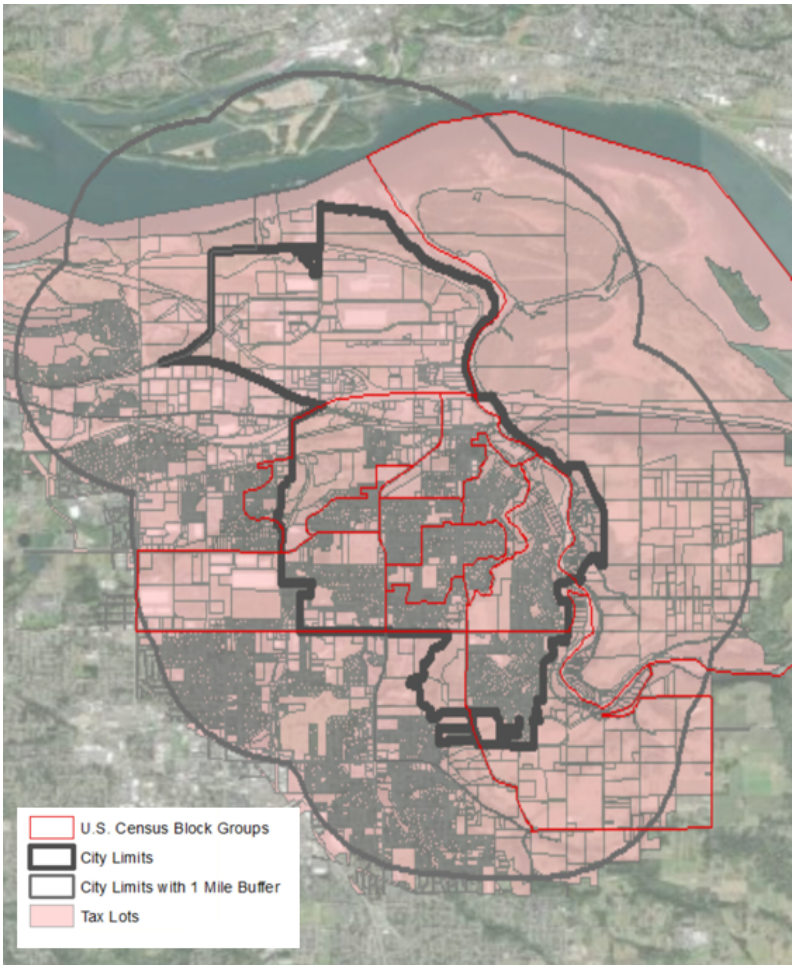

Figure. 1 *The boundaries used within this study*.

2.2 Data

To analyze the hazard vulnerability of Troutdale, data were obtained from various sources. Hazard data for the four identified hazards was gathered through the Oregon Wildfire Risk Explorer (wildfire), the Federal Emergency Management Association (flood), and the Statewide Landslide Information Database for Oregon (landslide and liquefaction). Upon narrowing down the most relevant social vulnerability indicators, data were acquired through the 2019 U.S. Census Data. This data included block group data as well as American Community Survey Data which generated a 5-year average. Finally, the critical infrastructure data used in this analysis was largely provided by the City of Troutdale Planning Department. Additional information was gathered using Google Point of Interest (POI) data which generated roughly 90 unique categories, some of which were included in this analysis.

2.3 Analysis Process

Upon obtaining hazard data, the data required the development of probability or threat levels. Wildfire, landslide, and liquefaction data generated four levels: none, low, medium, and high. Dialogue with Troutdale planners guided final flood threat level categorization to three threat levels: floodway, 100-year flood zone, and 500-year flood zone.

To analyze the risk of hazard threats upon Troutdale, community assets were located and inventoried. The categories used for this analysis included economic, critical infrastructure, critical facilities, and natural resources. After these data were located, the data were placed in relation with the hazard data to calculate the potential of loss based on each hazard and hazard level.

With these data in place, social vulnerability data was gathered. Researching existing social vulnerability indexes allowed us to identify the most pertinent social vulnerability indicators and four data points were decided upon: the elderly population over 65, children under 18, alternately abled or disabled population, and people below the poverty line. Placing these populations in relation to the hazard probability data, vulnerable populations were located in Troutdale.

3. SUMMARY OF FINDINGS

3.1 Overview

Flood Hazard Probability was found using three main criteria: severity (defined as magnitude, duration, and extent of flooding), probability of occurrence and the speed of flood onset. From this, we could place Troutdale's flood hazard into three categories: the floodway, 100-year flood zone and 500-year flood zone. The floodway

is the highest probability of flooding and is the area on either side of the river's channel which serves as a natural conduit for floodwaters. This area experiences flooding every second spring on average. The 100-year flood zone is considered medium risk based on the probability of flooding, which is defined as any area with a 1 in 100 (1%) chance of flooding every year. The 500-year flood zone is considered low to no risk since this area has a 1 in 500 (0.2%) chance of flooding each year.

The areas in Troutdale with the greatest probability of flooding are near the rivers, most especially on the eastern side of Sandy River but also along Beaver Creek. Outside of the city limits, but within the one-mile buffer, is the Columbia River floodway. The 100-year flood zone of the Columbia sits directly to the East of Troutdale.

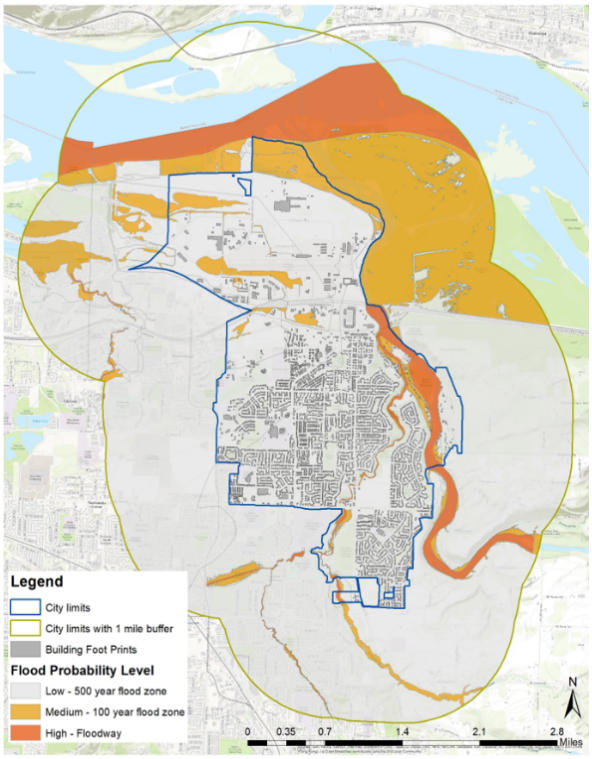

Figure 2. *Flood Probability in the City of Troutdale.*

3.2 Community Assets

To understand the impact of these high and medium flood probability zones on the community assets of Troutdale, we analyzed hazard levels in relationship to economic assets, community facilities, critical infrastructure, and natural resources.

3.2.1 Economic Assets

The Economic Assets of Troutdale were considered anything that brings revenue to the city. Here, we looked at tourist destinations and major employers. Of the Tourist

destinations of Troutdale, only one sits within the floodway (high risk) zone: Glenn Otto Community Park (Fig. 3). Although we could not find any tangible economic value for this park, we are confident that it has cultural value. In addition, it pulls in tourists from around Oregon, which certainly brings revenue to the shops and restaurants in Troutdale. The major employers we looked at were FedEx, Edgefield, and Amazon, none of which sit in either high or medium flood probabilities (Fig. 2).

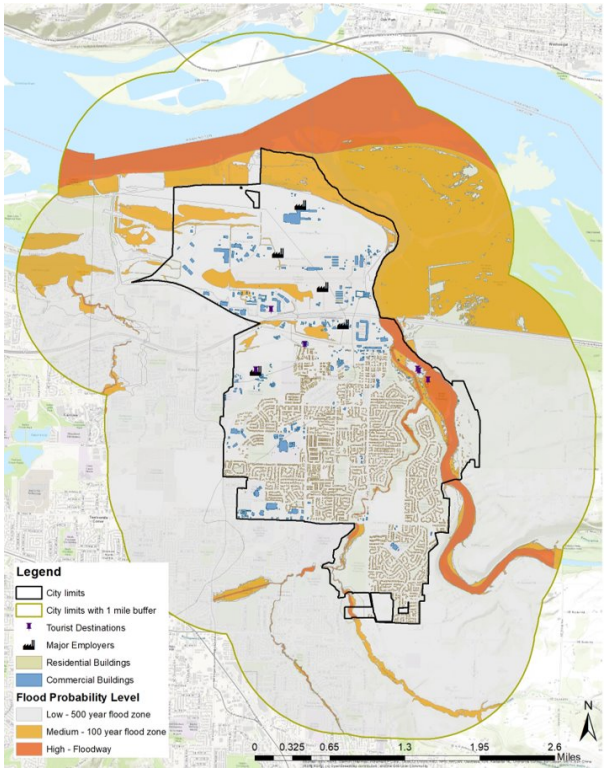

Figure 3. *Economic Assets compared to Flood Probability in Troutdale.*

Economy	500-year flood	100-yr Flood	Floodway
Jobs/Employers	6	0	0
Tourist Destinations	5	0	1
Commercial Buildings	390	8	0
Commercial Building ft^2	9,809,218	16,920	0
Residential Buildings	4769	28	0
Residential Buildings ft^2	24,377,556	50,853	0
Residential Buildings Value	$1,276,382,190	$15,021,880	$0

Table 1. *The value of the economic assets in Troutdale within the different flood probabilities.*

3.2.2 Community Facilities

The Community Facilities were defined as buildings and operations important to the innerworkings of the Troutdale community. This includes historical or cultural places, places of worship, public schools, child-care centers, nursing homes and mobile home parks. None of these were in high or medium flood probability zones.

Within this section we also looked at pre-1970s buildings. In the mid-1970s floodplain regulations were officially adopted into city zoning ordinances based on new requirements from the National Flood Insurance Program (Wright, 2000). For this reason, we focused attention on how many pre-1970s buildings might be in high or medium probability areas. We found several residential homes on the Eastern side of Sandy River located within the 100-year flood probability zone.

Figure 4. *Pre-1970s homes within the 100-year flood probability shown in grey.*

3.2.3 Critical Infrastructure

Critical infrastructure is defined as anything necessary for the health and safety of the Troutdale population. This was broken up into three main categories: emergency response, transportation, and utilities. Emergency response included emergency shelters, police stations, fire stations and hospitals. None of this infrastructure was found to be in a high or medium flood probability zone. Transportation included airports, boating facilities, bridges, railways, and transit routes (Fig. 4). The Portland-Troutdale Airport was found to be in the low-risk, 500-year flood zone. Two bridges and one boating facility were found to be within the medium and high flood probability zones (Fig. 5). Additionally, sections of railway and transit routes crossed through medium and high flood probability zones.

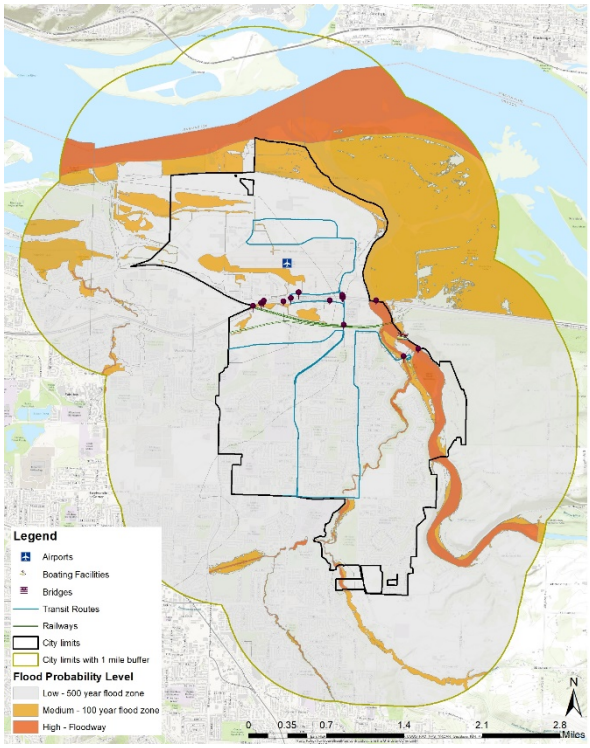

Figure 5. *Transportation Infrastructure compared to Flood Probability in Troutdale.*

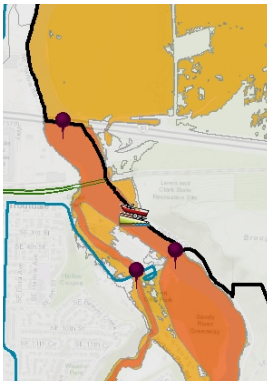

Figure 6. *Bridges, boating facilities, railways, and transit routes within 100-year flood zones and floodways.*

Finally, utilities included sewer pump stations, substations, transmission lines, water pipes, sewage pipes, and natural gas lines (Fig. 6). No sewer pump stations or substations were within the medium or high flood probability zones. Similar to the railways and transit routes, sections of transmission lines, water pipes, sewage pipes, and natural gas lines intersected medium and high flood probability zones.

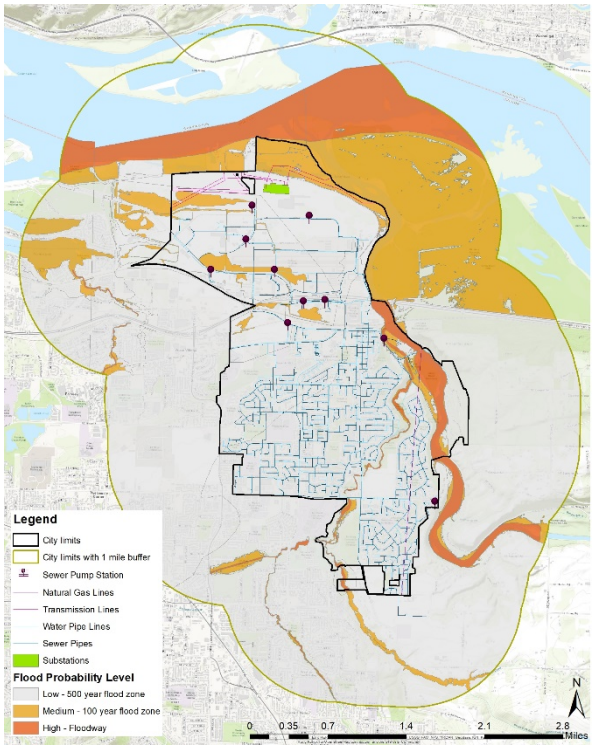

Figure 7. *Utility Infrastructure compared to Flood Probability in Troutdale.*

3.2.4 Natural Resources

Natural Resources are defined as any naturally occurring feature that is critical to the well-being of Troutdale. This includes parks, greenways, and agriculture tax lots (Fig. 7). Only one park, Glen Otto Community Park, is within a medium or high flood probability zone. Some sections of greenway overlap 100-year flood zones along the Sandy River and Beaver Creek. Finally, most agricultural tax lots are in low-risk zones, except for a sliver of 100-year flood zone that runs through the southern-most tax lots. While these tax lots are beyond the city limits, we included those inside the one-mile buffer due to their potential importance as a source of food and resources for the residents of Troutdale during a disaster.

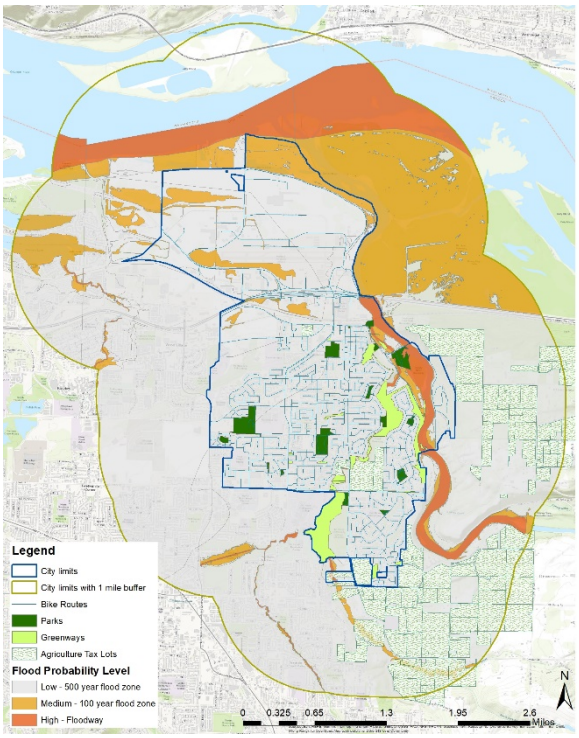

Figure 8. *Natural Resources compared to Flood Probability in Troutdale.*

3.3 Social Vulnerability

Beyond the risk associated with the physical and economic landscape of Troutdale, we analyzed hazard probability levels in relation to vulnerable communities. We focused on four communities: elderly people (over 65), children (under 18), people with disabilities, and people below the poverty line. For each of these indicators, we mapped the number of individuals within the community in each block group (Fig. 8). From these maps, we could see that there were a higher number of vulnerable individuals in the western-most block group, and there did not seem to be a disproportionate number of vulnerable individuals in the block groups that included the medium and high flood probability zones along the Sandy River.

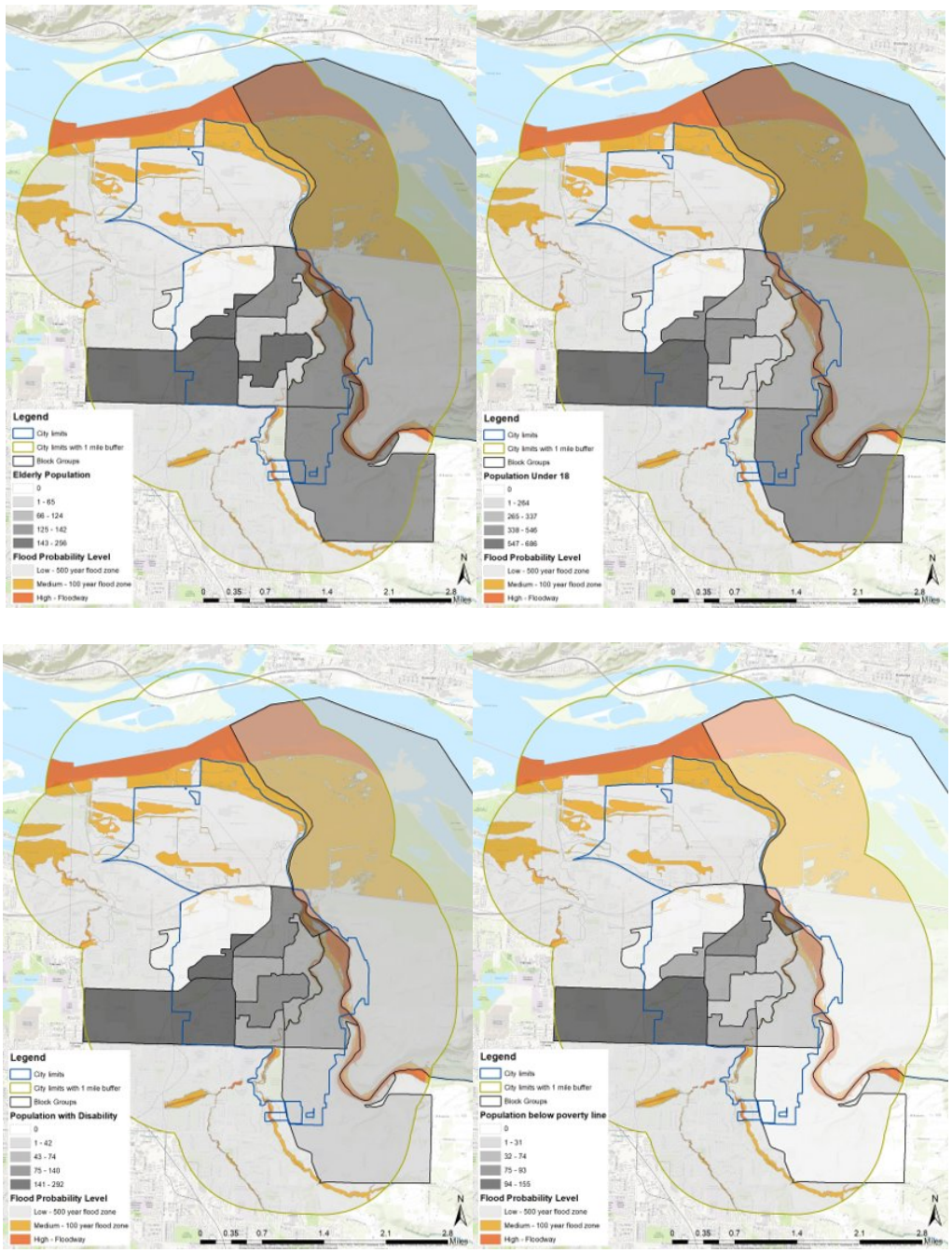

Figure 9. *Vulnerable Populations compared to Flood Probability in Troutdale. From left to right, top to bottom: Elderly individuals, children, people with disability, and people below the poverty line.*

Next, we estimated the number of vulnerable individuals residing in medium and high-risk areas by calculating the percentage of medium and high-risk areas in each block group and multiplying that percentage by the total number of vulnerable individuals in that block group (Fig. 9-12). For each population, we found a similar trend. The three block groups that intersect the Sandy River were estimated to have some vulnerable individuals residing in 100-year flood zones. This is most likely in the pre-1970's residential buildings mentioned above. There were no individuals

estimated to reside in floodways for these three block groups. Additionally, for each vulnerable population, the northeastern-most block group contained a relatively high number of vulnerable individuals in the 100-year flood zone. Notably, there were five elderly individuals estimated to reside in the floodway in this block group.

Blockgroup	Children in 500yr zone	Children in 100yr zone	Children in floodway	Total population of children
410510103031	1236	0	0	1236
410510103032	850	0	0	850
410510103051	509	8	0	517
410510103052	498	20	0	518
410510103053	453	3	0	456
410510103061	504	0	0	504
410510103062	706	0	0	706
410510103063	415	0	0	415
410510104022	840	0	0	840
410510105001	287	63	0	350
Total	**6298**	**94**	**0**	**6392**

Table 2. *Estimated number of children residing in flood probability zone per block group.*

Blockgroup	Elderly in 500yr zone	Elderly in 100yr zone	Elderly in floodway	Total Elderly
410510103031	311	0	0	311
410510103032	264	0	0	264
410510103051	204	2	0	206
410510103052	206	6	0	212
410510103053	62	1	0	63
410510103061	93	0	0	93
410510103062	277	0	0	277
410510103063	90	0	0	90
410510104022	246	0	0	246
410510105001	175	22	5	202
TOTAL	**1928**	**29**	**5**	**1964**

Table 3. *Estimated number of elderly individuals residing in flood probability zone per block group.*

Blockgroup	Total below poverty in 500yr zone	Total below poverty in 100yr zone	Total below poverty in floodway	Total population below poverty
410510103031	300	0	0	300
410510103032	175	0	0	175
410510103051	278	4	0	282
410510103052	88	4	0	92
410510103053	93	1	0	94
410510103061	258	0	0	258
410510103062	154	0	0	154
410510103063	316	0	0	316
410510104022	27	0	0	27
410510105001	166	37	0	203
Total	**1856**	**45**	**0**	**1901**

Table 4. *Estimated number of individuals below the poverty line residing in flood probability zone per block group.*

Blockgroup	Total disabled population in 500yr zone	Total disabled population in 100yr zone	Total disabled population in floodway	Total Disabled Population
410510103031	225	0	0	225
410510103032	291	0	0	291
410510103051	134	2	0	136
410510103052	69	3	0	72
410510103053	76	1	0	77
410510103061	79	0	0	79
410510103062	147	0	0	147
410510103063	86	0	0	86
410510104022	38	0	0	38
410510105001	39	9	0	48
Total	**1185**	**14**	**0**	**1199**

Table 6. *Estimated number of people with disabilities residing in flood probability zone per block group.*

4. DISCUSSIONS

In general, our analysis illustrates that the overall risk from flooding in Troutdale is low. There are no major employers or community facilities in the medium or high

hazard zones. The only park at risk is Glenn Otto Community Park, which is more resilient to natural flooding due to its ecology and function. Additionally, due to pre-existing zoning that limits development in floodways and 100-year flood zones, there are no buildings in a floodway and only 8 commercial and 28 residential buildings in a 100-year floodplain.

However, most of these 28 residential buildings were built before 1970, making them more vulnerable to potential floods. Also, we estimated that there are vulnerable populations residing in this hazard area. Further analysis could be beneficial to more accurately understand which vulnerable individuals reside within a hazard area and provide them the resources or information they need to mitigate their risk.

Other features that may require further analysis are the utility lines and transportation routes, both of which have sections that cross through hazard zones. It is unclear from our analysis whether this infrastructure is truly at risk, or if it was engineered to withstand floods. The City of Troutdale should investigate this and plan accordingly.

The Multnomah County Natural Hazards Mitigation Plan (MCNHMP) lists Troutdale as having a moderate risk of flooding, the second highest designation. A substantial portion of this NHMP focuses on the risk from channel migration of the Sandy River, a topic not included in our analysis. According to the MCNHMP, the Sandy River has a history of channel migration (documented in DOGAMI's Open-File Report O-13-10). Continued migration places hundreds of homes in Troutdale at risk. This is another topic that the City of Troutdale could investigate further.

5. REFERENCES

Federal Emergency Management Association. FEMA National Risk Index for Natural Hazards. Retrieved on June 5, 2021 from https://www.fema.gov/fr/flood-maps/products-tools/national-risk-index#:~:text=National%20Risk%20Index%20for%20Natural%20Hazards%20%28NRI%29%20The,expected%20annual%20losses%2C%20social%20vulnerabilities%20and%20community%20resilience

Multnomah County Emergency Management. 2017. *Multnomah County Multi-Jurisdictional Natural Hazards Mitigation Plan*. Retrieved on June 5, 2021 from https://multco- web7-psh-files-usw2.s3-us-west-2.amazonaws.com/s3fs- public/Approved 2017_MC_MJ_NHMP.pdf

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Wright, James M. Association of State Floodplain Managers. 2000. *The Nation's Responses to Flood Disasters: A Historical Account*.

Appendix B

Wildfire Final Report

Wildfire Risk

For the Sustainable City Year 2021 Project

PPPM 495: Advanced Geographic Information Systems

Allison Ahlert and Daisy Mills

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Findings and Summary

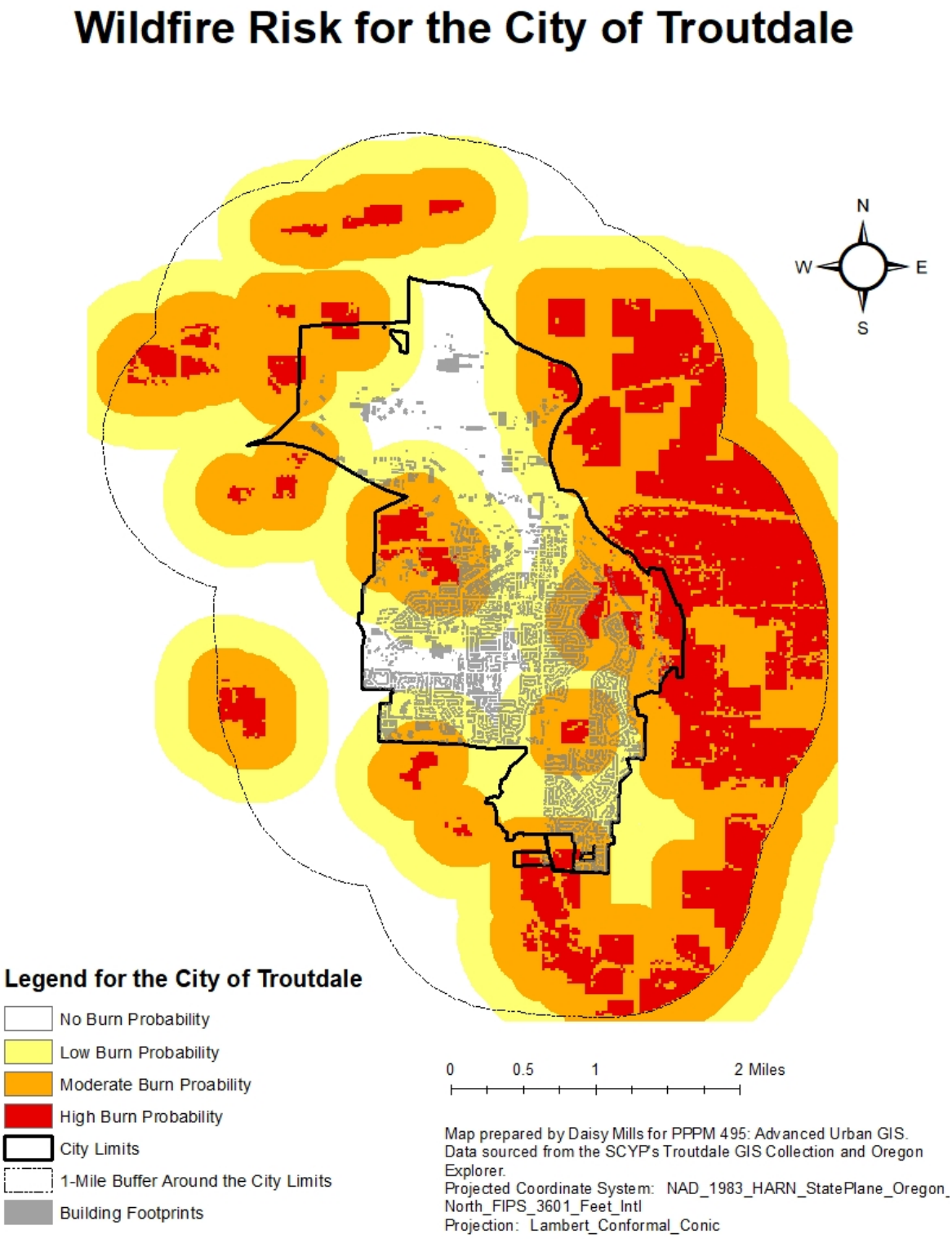


Figure 1

Overall Hazard Risk

The overall Wildfire Risk for the City of Troutdale was assessed using data from the Oregon Department of Geology and Mineral Industries. The layer downloaded from DOGAMI displays burn probability and originally displayed only areas of Oregon with a burn probability of 0 to 0.0001 or 1 in 10,000.[1] In their methodology, this is the lowest category of burn probability for the state of Oregon, and the only value that exists within Troutdale city limits. For comparison, the highest category of burn probability which exists in Oregon is 1 in 500.[2] After experimenting with reclassifying this data using manual breaks, our group decided to create burn probability zones using buffers to represent areas within a Euclidean distance from the areas with a burn probability value. Specifically, a burn probability > 0 constitutes high burn probability, areas less than 200 feet away from high burn probability zones constitute moderate burn probability, areas 200 to 500 feet away from high burn probability zones constitute low burn probability, and areas beyond 500 feet away from high burn probability zones constitute no burn probability. See Figure 1 which displays the Wildfire Risk for the City of Troutdale. The use of buffers to formulate our burn probability zones is intended to encapsulate the spreadable nature of wildfires while providing more detailed data for the City of Troutdale.

Figure 2 reveals that the majority of acreage within Troutdale city limits is in the No Burn Probability Zone (gray), followed by Moderate Burn Probability (orange), and Low Burn Probability (yellow). Looking back to Figure 1, a map highlighting Wildfire Risk in and around the City of Troutdale, it is evident that the majority of High Burn Probability area exists across the river and up into the Columbia River Gorge. Within city limits, three main regions of concern with regard to burn probability arise. Specifically, there are two clusters of high burn probability areas one along the Sandy Riverfront to the east and one near McMenamins Edgefield/Halsey Corridor. There is also a free standing area of high burn probability to the southeast residential area.

[1] "DOGAMI Geologic Mapping: Interactive Maps & Geospatial Data." *Oregon Department of Geology and Mineral Industries*, https://www.oregongeology.org/gis/index.htm. Accessed 8 June 2021.
[2] Julie W. Gilbertson-Day, Richard D. Stratton, Joe H. Scott, Kevin C. Vogler, and April Brough. "Pacific Northwest Quantitative Wildfire Risk Assessment: Methods and Results." Bureau of Land Management and US Forest Service, 2018.

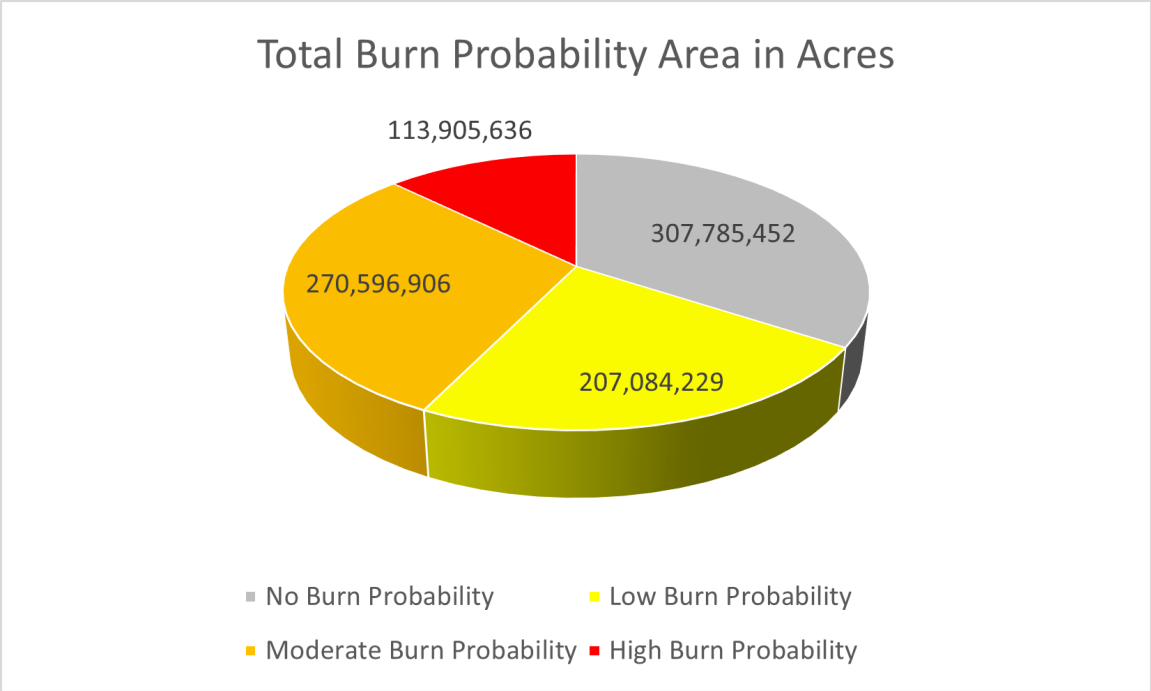

Total Burn Probability Area in Acres
113,905,636
307,785,452
270,596,906
207,084,229
No Burn Probability
Low Burn Probability
Moderate Burn Probability
High Burn Probability

Figure 2

Economic Assets

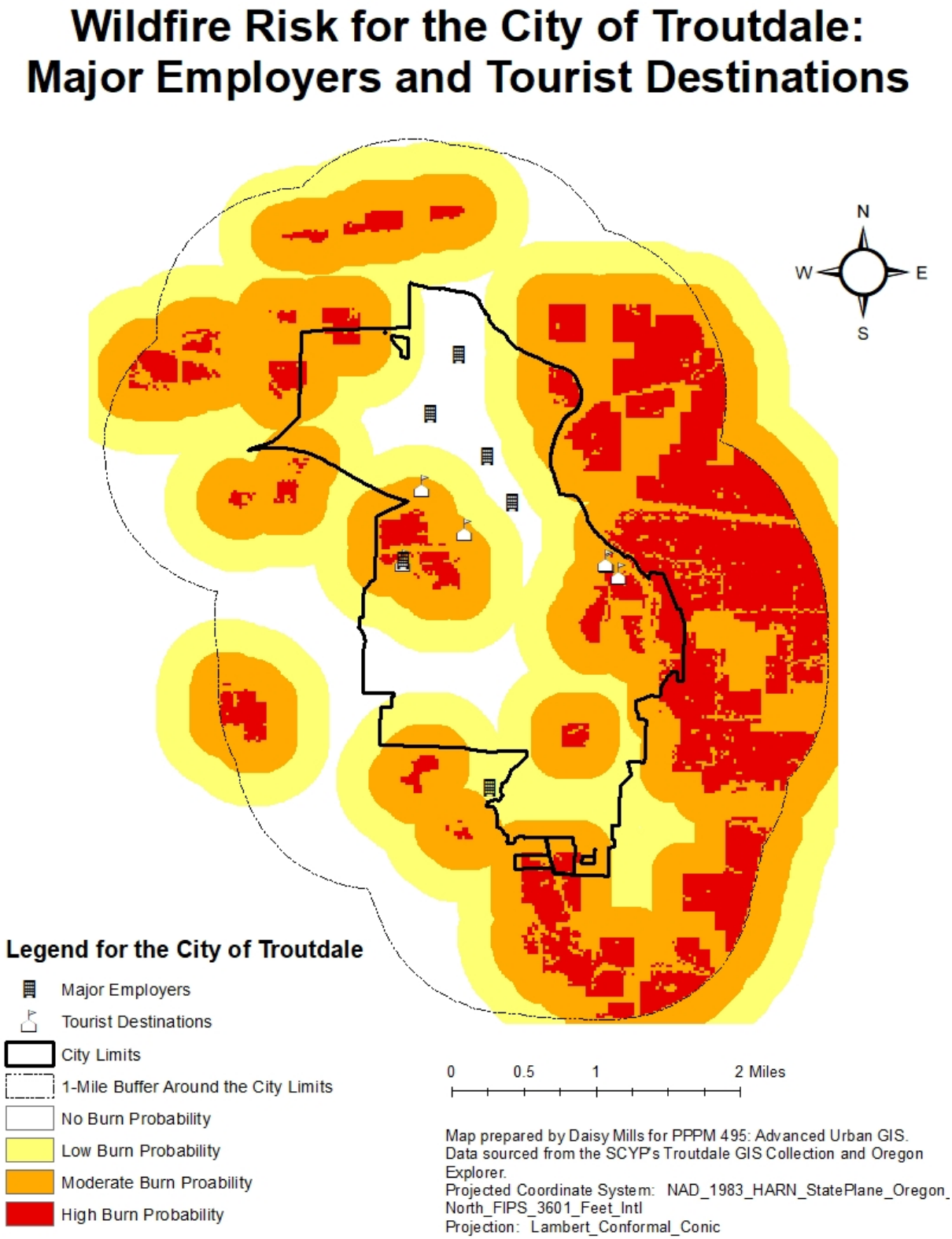


Figure 3

The primary map made by my group to understand the threat of wildfire to Troutdale's economic assets is seen in Figure 3, Wildfire Risk for Major Employers and Tourist Destinations. This map reveals that only one of Troutdale's major employers, McMenamins Edgefield, is located in a high burn probability zone, while the remaining sites including Mount Hood Community College, Columbia River Gorge Outlets, the Troutdale Airport, and FedEx and Amazon are located in no burn probability zones. Along those lines, in addition to Edgefield, Glenn Otto Community Park is the other tourist destination in a high burn probability zone while Sugar Pine, Historic Mainstreet, and Downtown are all in moderate burn probability zones. Overall, it is evident that McMenamins Edgefield and Glenn Otto Community Park and their earning potentials are at risk.

Preceding the creation of the Wildfire Risk for Major Employers and Tourist Destinations Map, our group joined building parcel data with tax lot data to estimate the economic value of various land parcels. Once this data was joined with our existing burn probability layer, the table showcased in Figure 4 was made to show the economic assets at risk in each burn probability zone by asset category. Key takeaways of this Wildfire Risk by Economic Asset table include the fact that there is around $2 billion of commercial buildings and $2 billion of residential buildings in burn probability zones and $2 million of agricultural land in high burn probability alone. Overall, Troutdale planners should focus attention on vulnerable tourist destinations and agricultural land in the face of wildfire risk.

Wildfire Risk by Economic Asset

Commercial Buildings		
	Burn Probability	Estimated Economic Value
	None	$1,403,586,490.00
	Low Probability	$1,337,067,310.00
	Moderate Probability	$1,179,415,400.00
	High Probability	$59,715,660.00
Residential Buildings		
	Burn Probability	Estimated Economic Value
	None	$1,105,128,210.00
	Low Probability	$1,236,516,870.00
	Moderate Probability	$1,236,516,870.00
	High Probability	$18,075,410.00
Mobile Home Parks		
	Burn Probability	Estimated Economic Value
	None	0
	Low Probability	0
	Moderate Probability	$13,798,320.00
	High Probability	0
Agricultural Land		
	Burn Probability	Estimated Economic Value
	None	0
	Low Probability	$985,560.00
	Moderate Probability	$1,162,290.00
	High Probability	$2,222,070.00

Figure 4

Critical Facilities

The primary map made by my group to understand the threat of wildfire to Troutdale's critical facilities is seen in Figure 5 on the following page, Wildfire Risk for Critical Facilities. This map symbolizes the locations of Public Schools, Places of Worship, Nursing Homes, Childcare Centers, and Mobile Home Parks within the various burn probability zones. The most important

piece of analysis gained from the Wildfire Risk for Critical Facilities map is that there are no critical facilities located within high burn probability zones. Specifically, there are two Mobile Home Parks with moderate burn probability; three Public Schools with low burn probability and one with No Burn Probability; one Place of Worship with moderate burn probability, two with low burn probability, and one with no burn probability; one Childcare Center with moderate burn probability; and one Nursing Home with low burn probability. Troutdale planners need not be overly worried with regard to critical facilities and wildfire risk.

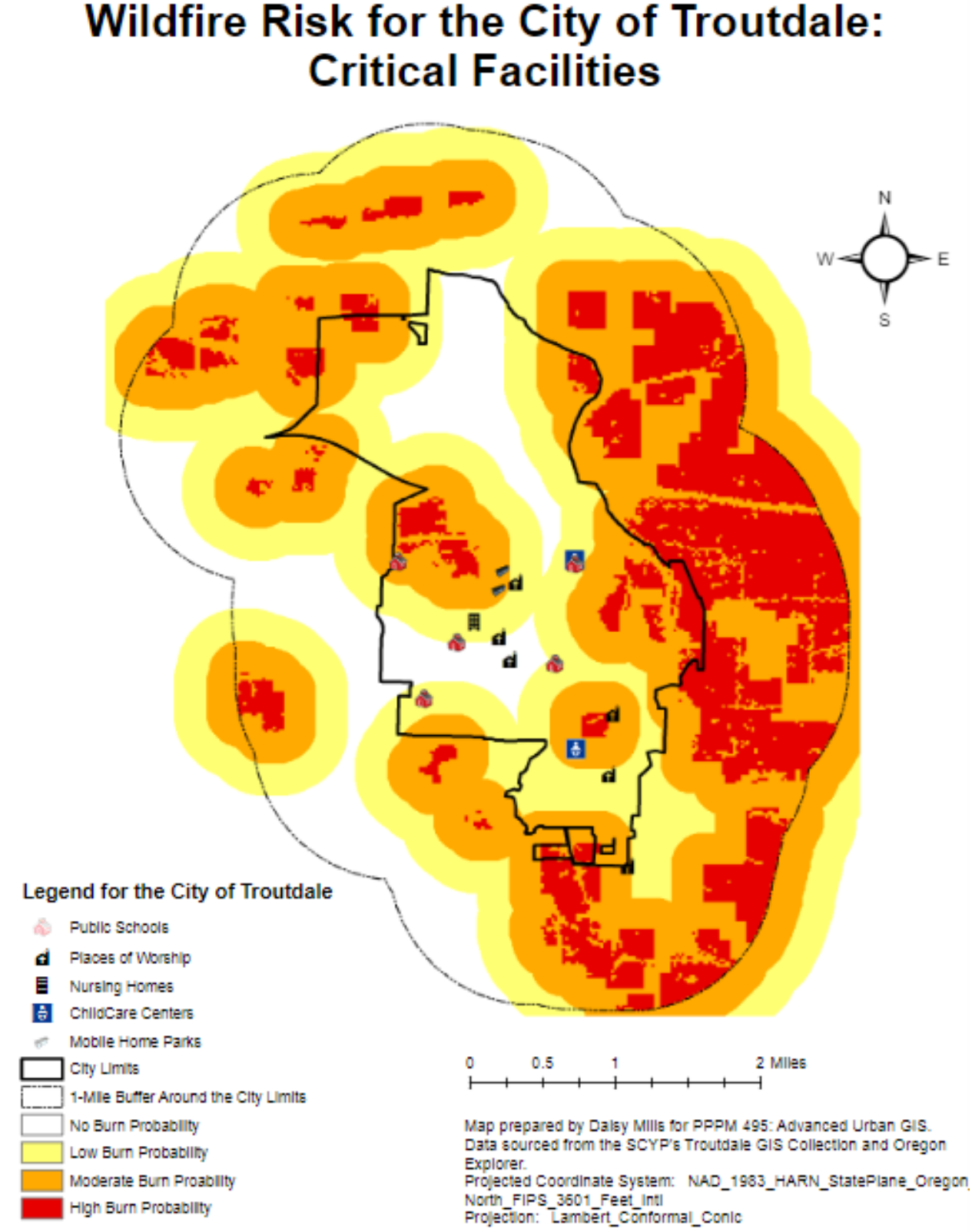

Wildfire Risk for the City of Troutdale:
Critical Facilities
N
W
E
S
Legend for the City of Troutdale
Public Schools
Places of Worship
Nursing Homes
ChildCare Centers
Mobile Home Parks
City Limits
1-Mile Buffer Around the City Limits
No Burn Probability
Low Burn Probability
Moderate Burn Proability
High Burn Probability
0
0.5
1
2 Miles
Map prepared by Daisy Mills for PPPM 495: Advanced Urban GIS.
Data sourced from the SCYP's Troutdale GIS Collection and Oregon Explorer.
Projected Coordinate System: NAD_1983_HARN_StatePlane_Oregon North_FIPS_3601_Feet_Intl
Projection: Lambert_Conformal_Conic

Figure 5

Critical Infrastructure

Critical infrastructure largely exists outside of the burn probability zones, however there are some exceptions that should be considered. The following sections summarize findings for transportation infrastructure, utilities, and emergency services.

Transportation

As seen on the transportation infrastructure map, this subset of the built environment largely skirts burn probability zones, although a moderate amount exists in the moderate probability zone. In the chart below we can see that only 3.5 miles of Troutdale's roads are within the high probability zone, but nearly 20 miles of roads are within the 200-foot distance of these zones. Although there is a small number of miles of railway within the high probability zone in Troutdale, it should be noted that the railway passes through a longer distance of high burn probability to the West of Troutdale and any impact to the line would effectively shut down the entire length as reroutes would take rail traffic off the line completely.

Burn Probability	Roads (miles)	Railways (miles)
None	14.2	1.3
Low Probability	23.7	0.2
Moderate Probability	19.3	4.1
High Probability	3.5	0.8

Figure 6

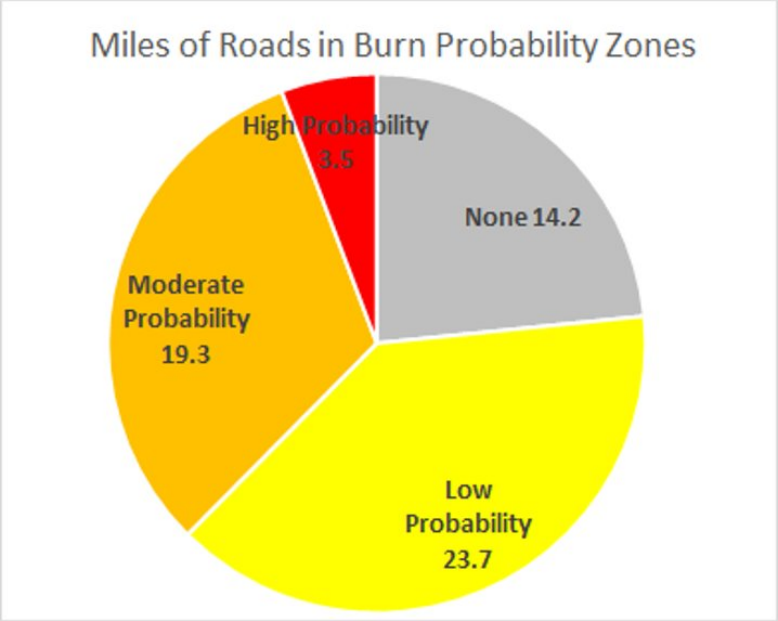


Figure 7

There are no bridges in the high burn probability zones for Troutdale, but significantly there are eight bridges in the moderate probability zone. These are all located on and near the I-84 corridor, making this element of connectivity extremely important for hazard mitigation priorities. Notably, as seen on the table below, the detour lengths for these bridges are nearly double those in the low and no probability zones, making the impact to traffic very high should they be taken out of use.

Troutdale Bridges

Burn Probability	Count	Sum of Detour Lengths
None	**3**	4
Low Probability	**5**	12
Moderate Probability	**8**	57.41
High Probability	0	0

Figure 8

Other transit facilities such as transit stops, and major hubs like airports and ports are less impacted by burn probability zones. The Troutdale airport is in the no probability zone. The

number of transit stops within moderate and low probability zones can be seen on the table below. Further analysis of transit routes that may be impacted by wildfire and how the populations they serve could be impacted is recommended.

Other Transit Facilities

Burn Probability	Airports, Boating and Port Facilities	Transit stops
None	**1**	**15**
Low Probability	**0**	**28**
Moderate Probability	**1**	**24**
High Probability	**0**	**0**

Figure 9

Utilities

Since utilities are largely placed with public roads, the exposure to wildfire is similar. There are very few miles of sewer pipes and water pipes in high burn probability zones. Similarly, there are no sewer pump stations or electrical substations within high burn probability zones. A summary table of these can be seen below. Of note are natural gas lines, which do intersect high probability zones and moderate probability zones, running north to south on the west side of Troutdale.

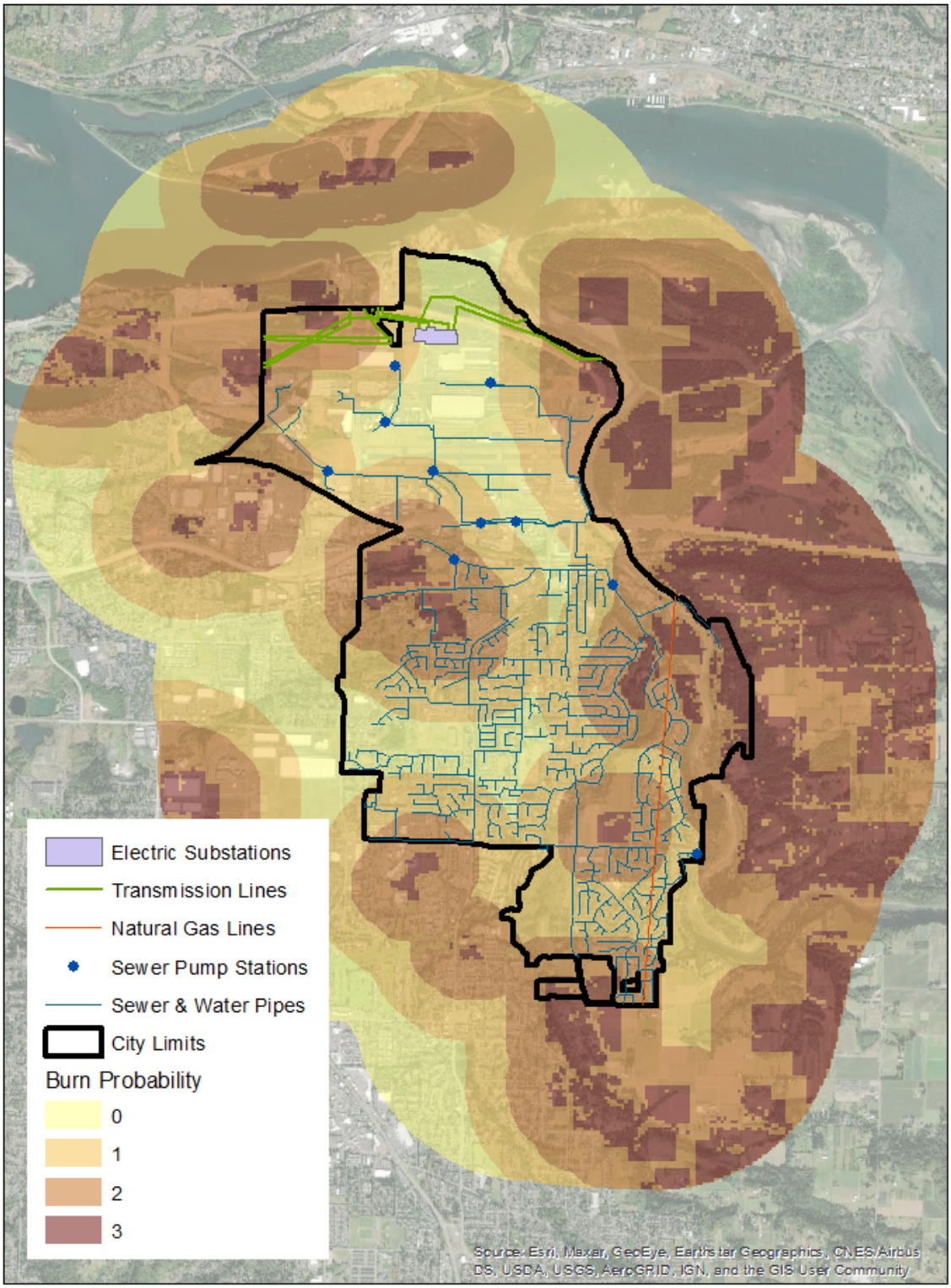

Electric Substations
Transmission Lines
Natural Gas Lines
Sewer Pump Stations
Sewer & Water Pipes
City Limits
Burn Probability
0
1
2
3
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 10

Sewer pump stations	Electric Substations	Water pipes (miles)	Sewer pipes (miles)	Transmission line (miles)	Natural gas line (miles)
2	1	15.1	10.5	35.7	0
4	0	31.2	25.1	16.8	0.5
3	0	23.7	21.5	22.6	1.6
0	0	1.3	1.0	0	0.2

Figure 11

Emergency Services

Emergency facilities of Troutdale are not significantly at risk of being burned in a wildfire. As seen on the chart below, 3% of hospitals, police and fire stations, and shelter facilities exist in the high burn probability zone. As seen on the emergency services map, one hospital does exist in the moderate probability zone, that is, within 200 feet of the area with burn probability. Another hospital and the fire station are within the low probability zone.

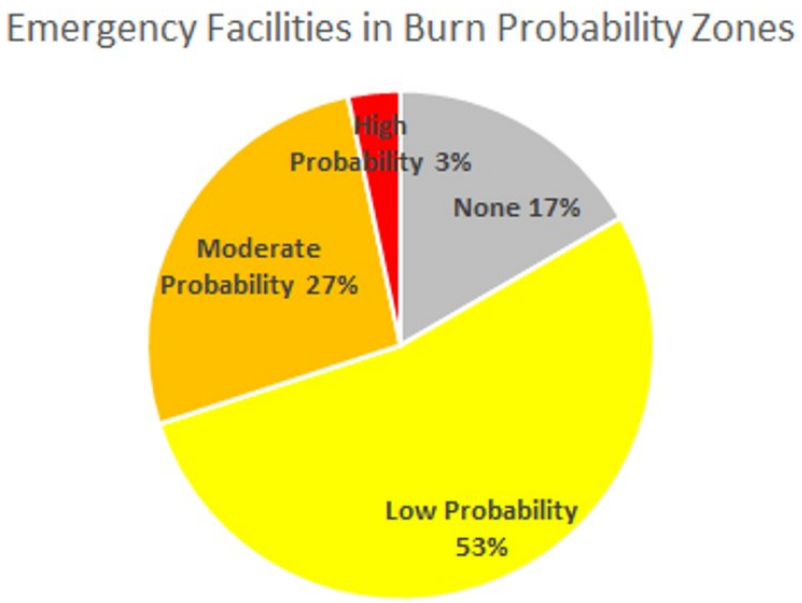


Figure 12

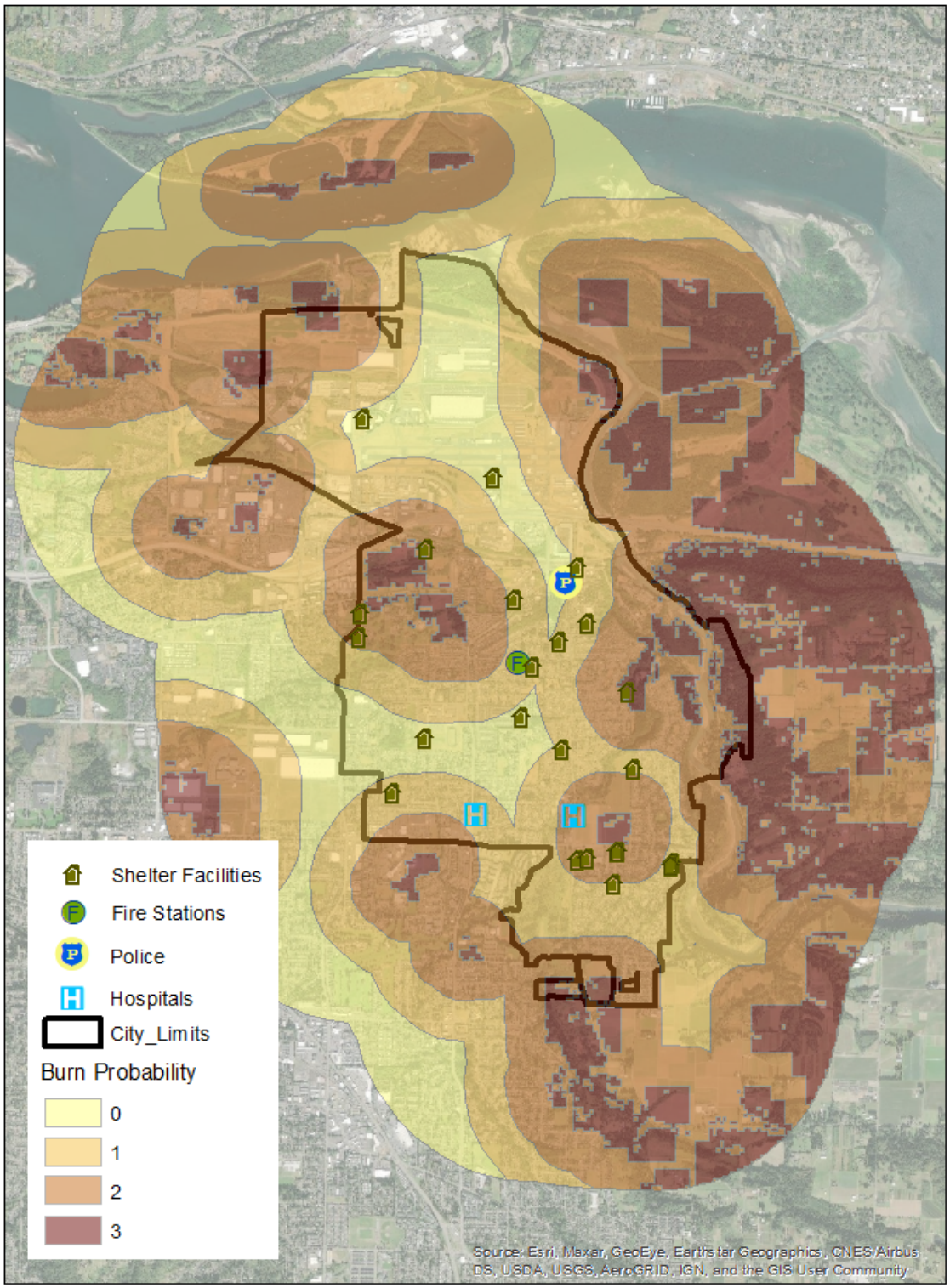

Shelter Facilities
Fire Stations
Police
Hospitals
City_Limits
Burn Probability
0
1
2
3
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 13

Natural Resources

Troutdale's natural resources were found to be the only sector of community assets that have a significant risk of burning in a wildfire. As seen in the chart below, by acreage, 30% of Troutdale's parks and greenways are in the high probability zone. Compared to the other asset sectors we looked at which had between 0 and 5% of their elements within the high probability zone, green spaces are significantly at risk of burning. A summary table of natural resources by acreage can be seen below.

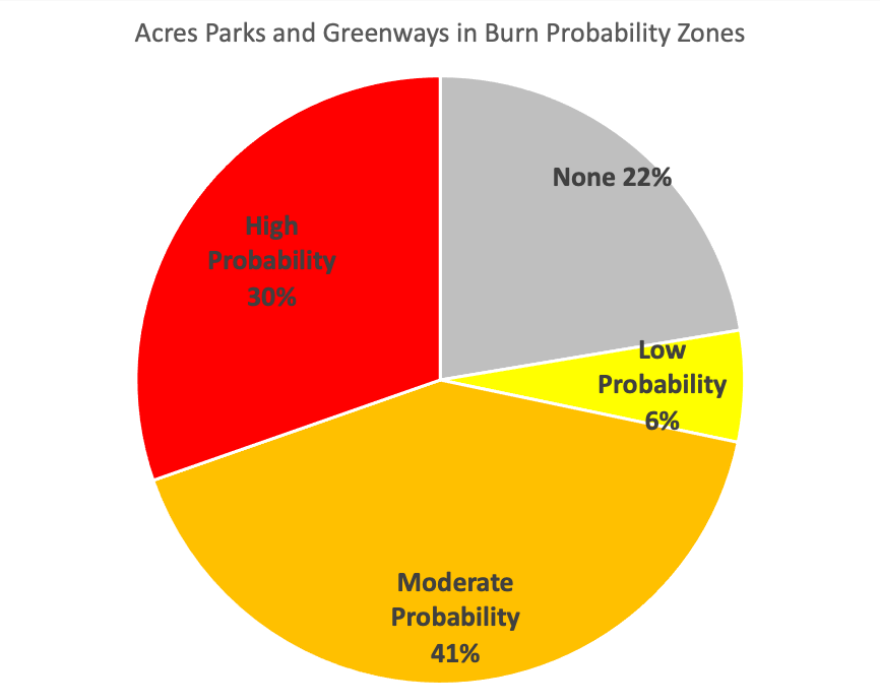


Figure 14

Burn Probability-Acres	Parks	Greenways	total
None	52	2.1	54.1
Low Probability	4.1	10.2	14.3
Moderate Probability	31.7	68.3	100
High Probability	0	73.4	73.4

Figure 15

Another significant area of risk is agricultural land. On the map, we see that most of Troutdale's agricultural land is one large tract in the south-central part of the city. More than half of this large parcel intersects the high probability zone. There is also another tract of agricultural land entirely within the high probability zone on the southern end of the city limits. The total acreage in high probability burn zone is over 4000 and is valued at over two million dollars. This comprises most of Troutdale's agricultural land and over half of the total value of agricultural land in Troutdale.

Burn Probability	Area (acres)	Economic Value
None	0	**0**
Low Probability	20.8	$935,560.00
Moderate Probability	104.9	$1,162,290.00
High Probability	4103	$2,222,070.00

Figure 16

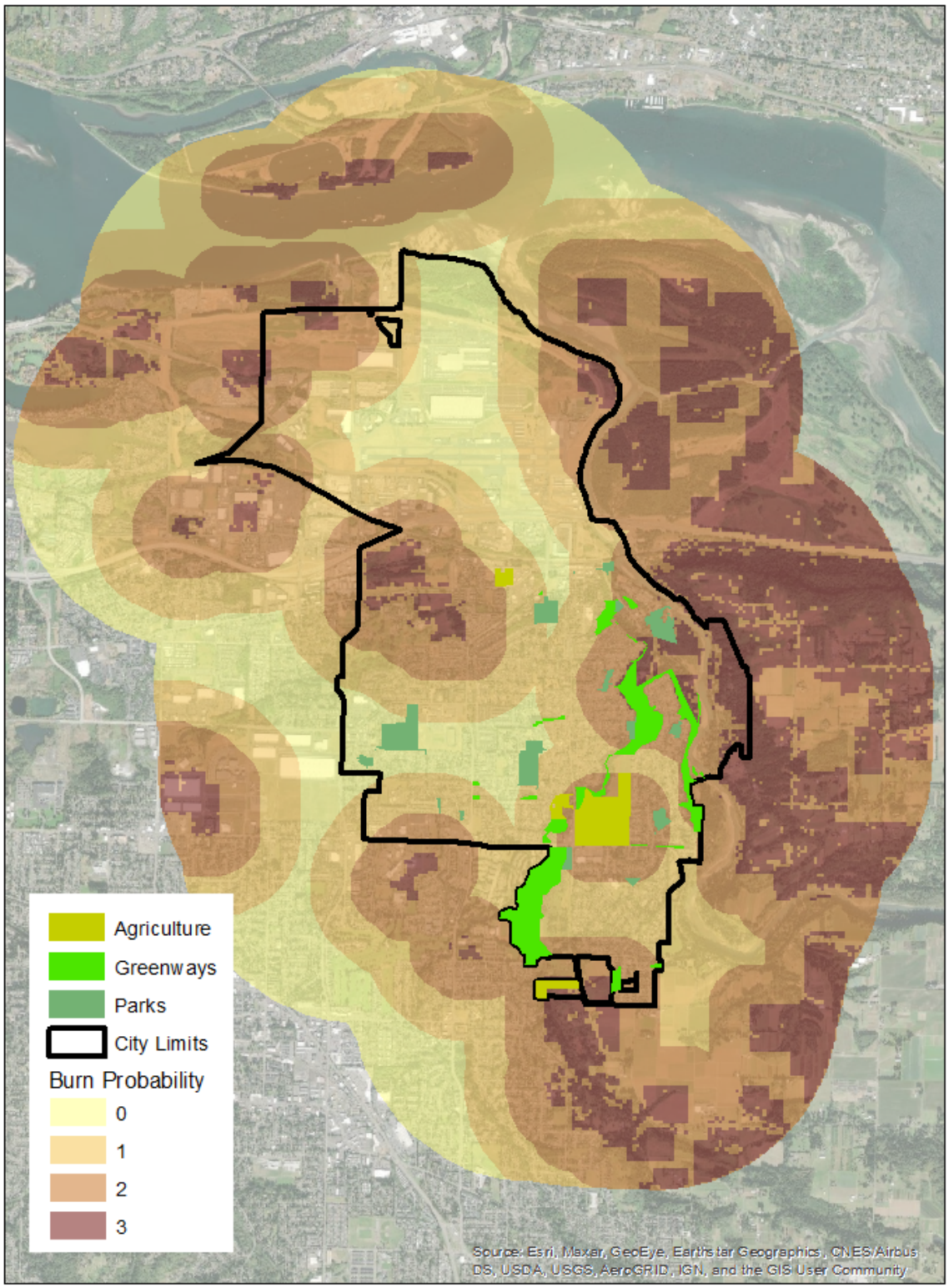

Agriculture
Greenways
Parks
City Limits
Burn Probability
0
1
2
3
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 17

Social Vulnerability

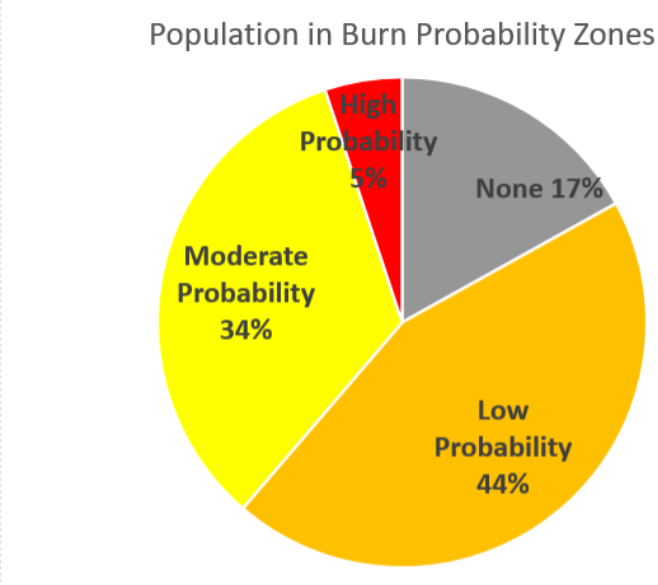


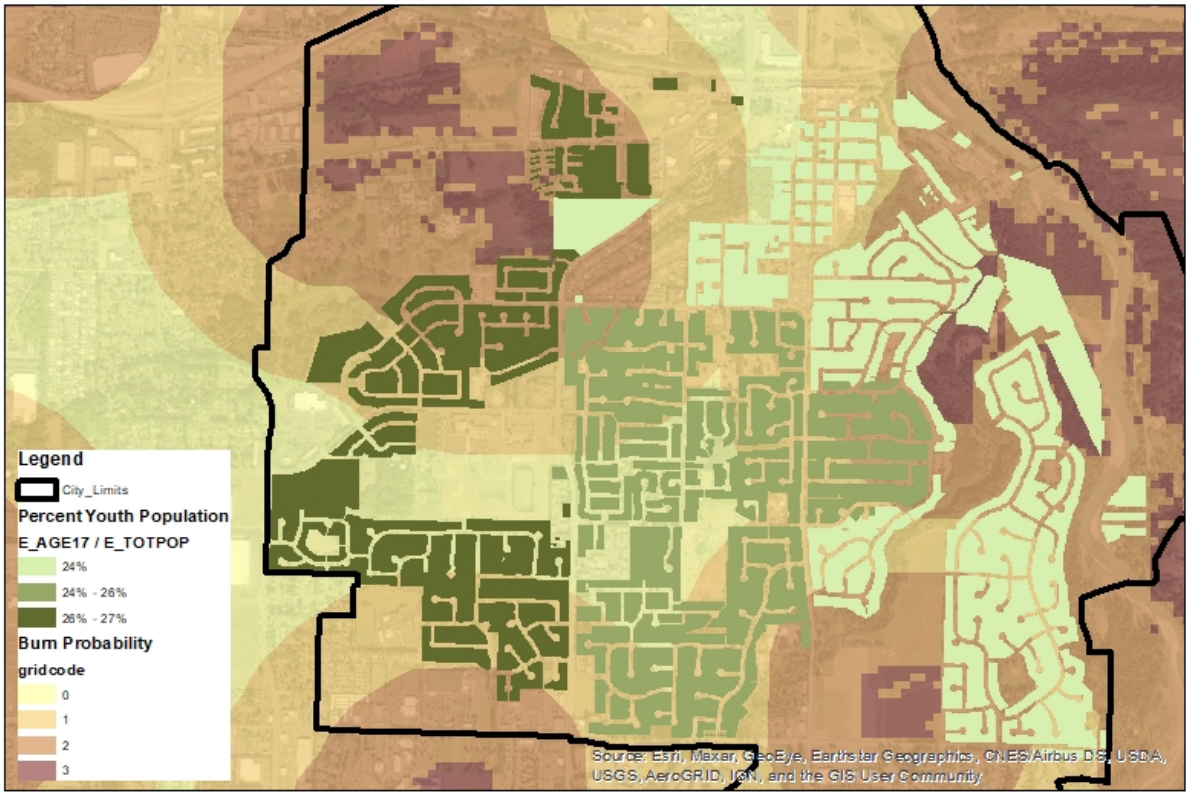
Figure 18

Figure 18 shows the percentage of total Troutdale population in each Burn Probability Zone. This pie chart reveals that the majority of the population is in low burn probability zones while only a very small percentage are in high burn probability zones. While it is good news that so few vulnerable residents reside within high burn probability zones, it should be noted that the impacts of wildfire anywhere in the vicinity of Troutdale will disproportionately affect these vulnerable populations. A community's social vulnerability is defined by many factors — such as socioeconomic status, household composition, race and ethnicity, and vehicle access — that increase and decrease individual and collective resources to anticipate, survive, and recover from natural hazards and disasters. In the U.S., poor people are more vulnerable at all stages of a catastrophic event, as are non-white people, non-native English speakers, children, elderly, and disabled people.[3] Socially vulnerable communities experience higher rates of mortality, morbidity, and property destruction and are less likely to fully recover from a disaster. Our analysis describes these residents' exposure to burn probability. However, the location and concentration of these populations should be used to plan for over-all mitigation and resilience as impacts of regional wildfires outside of burning, such as air quality and transportation interruptions, will impact these people more than others.

[3] Flanagan, Barry E. et al. "Measuring Community Vulnerability to Natural and Anthropogenic Hazards: The Centers for Disease Control and Prevention's Social Vulnerability Index." Journal of Environmental Health. 2018. Vol. 80, Num. 10. Pages 34–36. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7179070/

In pursuit of understanding how vulnerable populations are affected by the Overall Wildfire Risk for the City of Troutdale, our team downloaded data from the 2019 American Community Survey covering Youth, Elderly, Impoverished, and Disabled Populations. This data was normalized by the total population of each BlockGroup and reclassified using natural breaks to formulate the maps seen in Figures 19 and 20.

Figure 19 highlights the Distribution of Youth and Elderly Populations in Troutdale across Burn Probability Zones. The green map uptop of Figure 19 reveals that Youth Populations are concentrated in western Troutdale, somewhat near the Edgefield/Halsey Corridor cluster of high burn probability zones while the blue map below reveals that Elderly Populations are concentrated to the east, immediately adjacent to the cluster of high burn probability zones along the Sandy River. Based on these observations, it can be understood that these vulnerable populations are at substantial risk with regard to wildfire.


Legend
City_Limits
Percent Youth Population
E_AGE17 / E_TOTPOP
24%
24% - 26%
26% - 27%
Burn Probability
gridcode
0
1
2
3
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

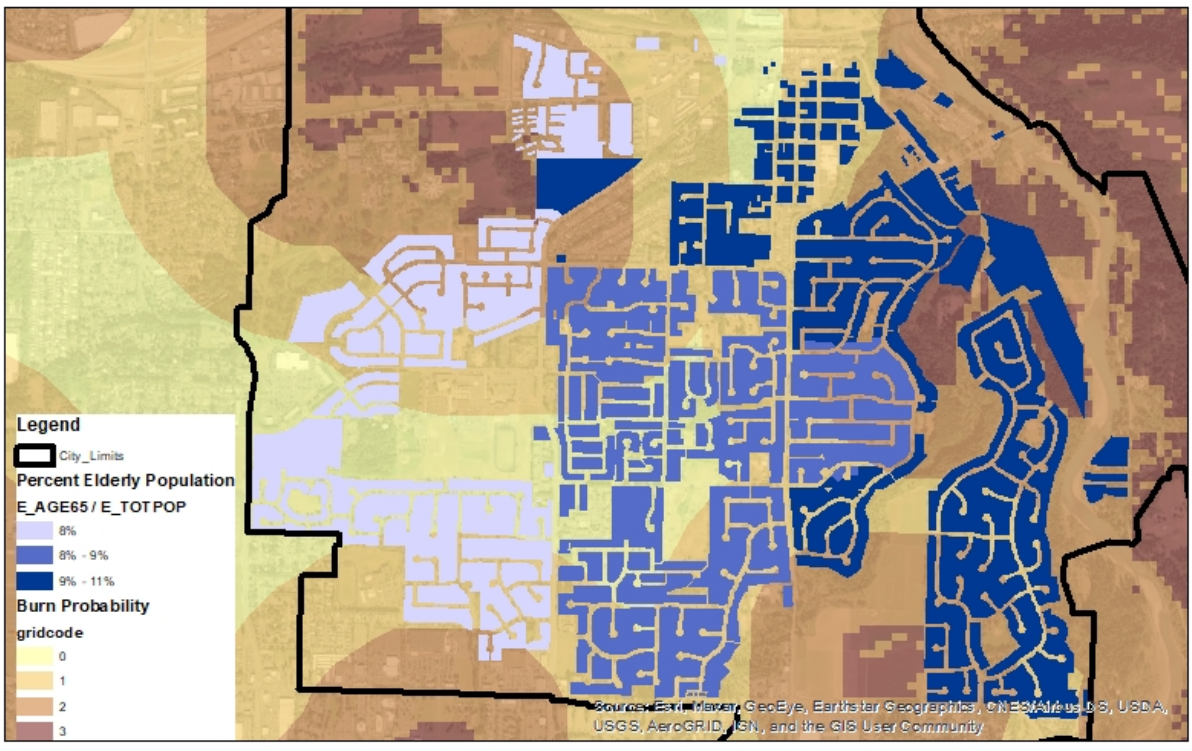

Legend
City_Limits
Percent Elderly Population
E_AGE65 / E_TOTPOP
8%
8% - 9%
9% - 11%
Burn Probability
gridcode
0
1
2
3
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 19

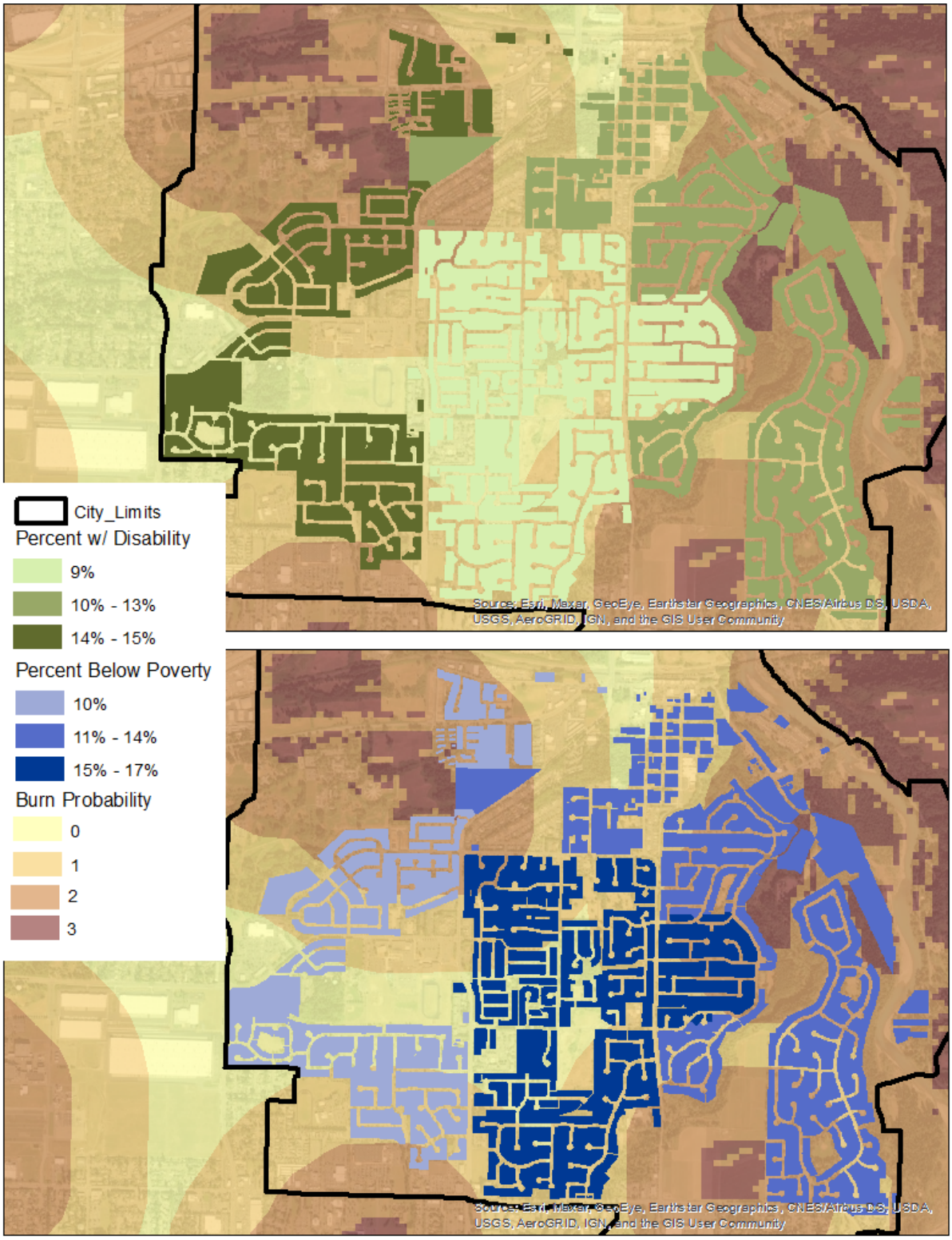

City_Limits
Percent w/ Disability
9%
10% - 13%
14% - 15%
Percent Below Poverty
10%
11% - 14%
15% - 17%
Burn Probability
0
1
2
3
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 20

Similar to youth and elderly populations, populations living with disability and in poverty highlighted in Figure 20 are distributed irregularly across the residential areas of Troutdale. In the map below, we can see that the area with the highest concentration of differently abled is on the west side of the city, with a small portion adjacent to, but not within, a high probability burn zone. Those experiencing poverty are most highly concentrated in the central part of Troutdale's residential areas, mostly in the low and no probability zones. However, on the east side of the city, both these populations are moderately concentrated, between 10 and 14% of the population. This eastern portion of the city is much more exposed to burn probability. As seen on the map, much of the buildings are in the moderate probability zone and/or adjacent to high probability zones. These areas, although they have lower concentrations of vulnerable populations, are a priority because they have higher levels of exposure.

Discussions and Recommendations

Our analysis of wildfire risk for the City of Troutdale concluded that burn probability within city limits is very low. Only a small portion of the city has a probability of burning, and this probability is less than 0.01%. Though this qualitative information tells us that the risk of wildfire is low, DOGAMI officials explain that the risks of wildfire are actually much greater than 1 in 10,000 when the impacts of regional wildfires such as evacuation traffic and populations, air quality, etc. are considered. In other words, it is not just the high burn probability zones of Troutdale that are at risk, it is all of the areas that surround them.

Moving forward to our vulnerability assessment, it was concluded that elements of the built environment such as transportation and utilities infrastructure, and critical facilities, and residential and commercial buildings are not significantly in danger of burning. These assets are less likely to be impacted by the affects of nearby or regional wildfires such as diminished air quality. Despite this low risk, special attention should be given to the following community assets, which are at some risk of burning: tourist destinations McMenamins Edgefield and Glenn Otto Community Park, as well as agricultural lands, greenways, and parks. Exploring the risk of wildfire to Troutdale residents, it was affirmed that vulnerable populations will be impacted most by wildfire, whether in the city limits or nearby. Special consideration should be taken in building resilience to all hazards in the areas these residents are concentrated.

Along those lines, our group has assembled a short list of policy recommendations for Troutdale city planners to take under consideration. General policies likely to increase resilience across hazard types include increasing awareness of high-threat/high-vulnerability residents with pocket response plans, back-up supplies, awareness of evacuation routes, and personal evacuation plans; placing signage on hazards and evacuation routes at tourist destinations; identifying and coordinating city-level emergency response partners; identifying alternative routes when I-84 is

impacted; locating funding to retrofit transportation, utility, and emergency response infrastructure; and partnering with city or county level organizations to provide housing options and shelter locations away from high hazard risk areas.

Policies more specialized to the threat of wildfire are primarily focused on fuel reduction. Such policies include providing support to agricultural property owners and residential areas near greenspace; integrating urban design and landscaping for further fuel reduction; and targeted grazing using cattle. One more advanced option is revitalizing traditional ecological knowledge through Indigenous land management practices such as increased frequency and scope of controlled burns to intervene into the seasonal fire regime.[4] Despite the overall low wildfire risk for the City of Troutdale, planners should take these recommendations seriously and engage with policy solutions as the threat of wildfire grows beyond the scope of DOGAMI data due to our warming climate.

References

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Julie W. Gilbertson-Day, Richard D. Stratton, Joe H. Scott, Kevin C. Vogler, and April Brough. "Pacific Northwest Quantitative Wildfire Risk Assessment: Methods and Results." Bureau of Land Management and US Forest Service, 2018.

"Karuk Climate Change Projects." *Karuk Climate Change Projects*, 2016, https://karuktribeclimatechangeprojects.com/.

[4] "Karuk Climate Change Projects." *Karuk Climate Change Projects*, 2016, https://karuktribeclimatechangeprojects.com/.

Appendix C

Landslide Final Report

Landslide Susceptibility

Class Project Final Report for PPPM 495/595 Advanced GIS

Larson-Friend, John
Kleinsmith, Cody
Meng, Sian

June 11, 2021

Table of Content

1. PROJECT BACKGROUND AND RESEARCH OBJECTIVES

Global climate change has increased the frequencies and the severity of communities' exposure to natural hazards. Communities in the Northwest have become increasingly vulnerable to such hazards as wildfire, flooding, landslide, and earthquakes. Risk assessment is a necessary step in a community's effort to devise effective and efficient hazard response strategies. Our class project aims to map the spatial distribution of hazard risks and assess their economic and social impacts from the four types of natural hazards in the City of Troutdale.

2. METHODOLOGY

2.1. Study Area

The study area includes Troutdale's territory and a one-mile buffer of the City.

2.2. Data

There are three types of data we used for landslide risk analysis:

- Hazards: Flood hazard (100-year flood plains), Landslide hazard (landslide susceptibility overview map of Oregon), Earthquake hazard (expected earthquake shaking}, wildfire (wildfire risk)
- Assets: City of Troutdale's ArcGIS dataset and Google POI (Point of interest) data
- Demographic characteristics: 2019 U.S. Census Data (Block Groups) and 2019 American Community Survey Data (5-Year Average)

2.3. Analysis Process

Following the USGS, risk can be thought of as "the intersection between hazards and assets." Assets encompass "all the things that make a community livable, including the people, land use/zoning and buildings, critical facilities, and primary infrastructure such as transportation corridors, electrical transmission lines, dams, and so on." The National Risk Index methodology provides a more comprehensive definition of "risk" that takes into consideration of social vulnerability and community resilience, both of which are measured with demographic characteristics.

In this project, we overlay two input factors — hazard and assets —to map the areas where risks exist. We study the potential physical, economic, and social impacts on those areas from various hazards by inventorying affected facilities and estimating possible property value loss. We also identify places of high vulnerability by examining the location of socially disadvantaged populations in relation to the risk areas.

3. SUMMARY OF FINDINGS

3.1. Overview

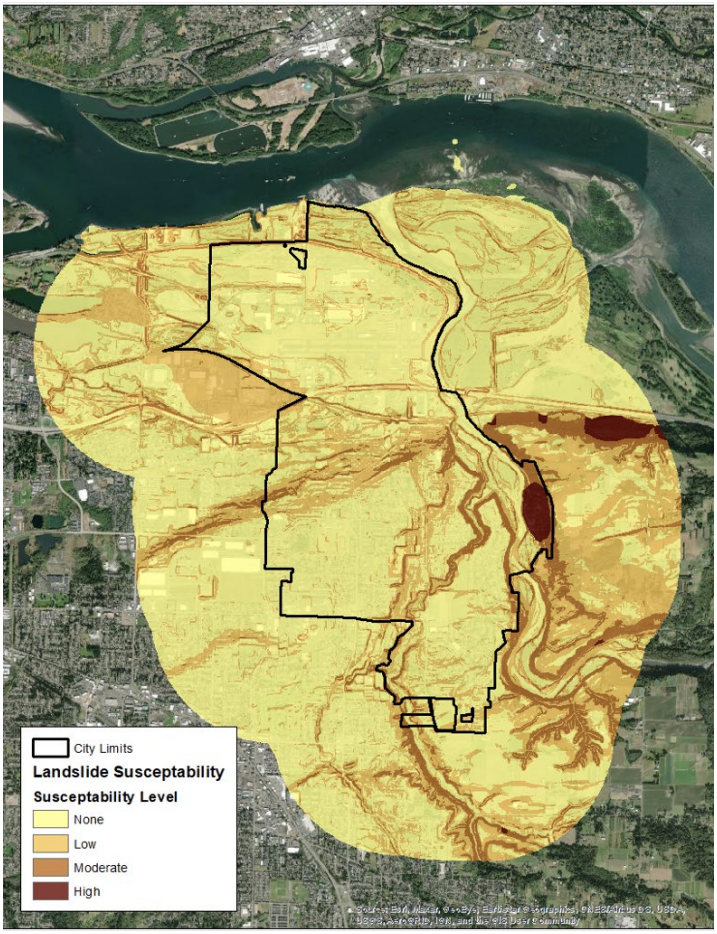
Landslide susceptibility is one of the less concerning natural hazards for Troutdale. The overall distribution of the hazard levels can be viewed in Table 1, which shows that only 10% of Troutdale is within the moderate and high-risk areas, and only 1% is within the high-risk areas alone.

Table 1. Overall Landslide Susceptibility in Troutdale

Hazard Level	Percentage of Troutdale Land Within Risk Category
No Risk	60%
Low Risk	30%
Moderate Risk	9%
High Risk	1%

Beyond the numbers, we also can see how the landslide risk is distributed spatially throughout the city. Figure 1 shows an overview of Troutdale's landslide susceptibility throughout the city and buffer area.

Figure 1. Overall Landslide Susceptibility Map



The first area worth noting is the area of high risk on the eastern extremity of Troutdale's city limits. This area is a historic landslide and is the only area of high risk within the city boundary. This area's high-risk status comes from the disturbed soils that resulted from that historic landslide as well as the existing slopes of the region. It is worth noting that in addition to this former landslide, the majority of the region to the east of this high-risk area is higher in average risk level than the current Troutdale city limit area, which should be considered and analyzed in future Metro UGB expansion or urban reserve planning.

adjacent to the Sandy River and Beaver Creek streambeds. As is apparent on the map, these areas are typically in the moderate risk category largely due to the high presence of water to erode the soil base as well as the higher slopes than much of the rest of Troutdale. These areas will be critical to plan for during floodplain management and flood hazard planning as flood events can increase the susceptibility for landslides compared to normal circumstances.

The third area to highlight is the bluff that runs from west-southwest to east-northeast across the portion of the city south of Interstate-84. This bluff has more low-risk and some moderate-risk areas that are largely due to the slopes of this bluff. While not a priority compared to the previous two zones, it should still be taken into consideration for landslide planning moving forward.

The final area to highlight is the portion of Troutdale situated between Interstate-84 and the Columbia River. This area is largely flat and lacks any significant stressing features, so it is almost entirely composed of the no-risk category. When planning for landslides, this area should be last on the list, and other hazards should be prioritized in this area.

To summarize our overall analysis of the landslide susceptibility in Troutdale, the vast majority of the city is in no-risk or low-risk areas. Particularly large sections of the city in the northern, southwestern, and southern regions lack any significant risk at all. The primary areas of risk are the historical landslide on the eastern extreme of the city boundaries and the slopes directly adjacent to the Sandy River and Beaver Creek. Landslide susceptibility can largely be covered in policies and targeted efforts in these regions, and tactical deployment of funds and staff to undertake these efforts on small scales can have a large impact on this hazard.

3.2. Community Assets

3.2.1. Economic Assets

An analysis of the economic assets we identified in Troutdale returns similar trends to the overall analysis, which is to say that landslide susceptibility threatens very limited amounts of the economic assets. To look at the whole of the economic asset analysis, we can refer to Table 2, which summarizes our data.

Table 2. Economic Asset Summary

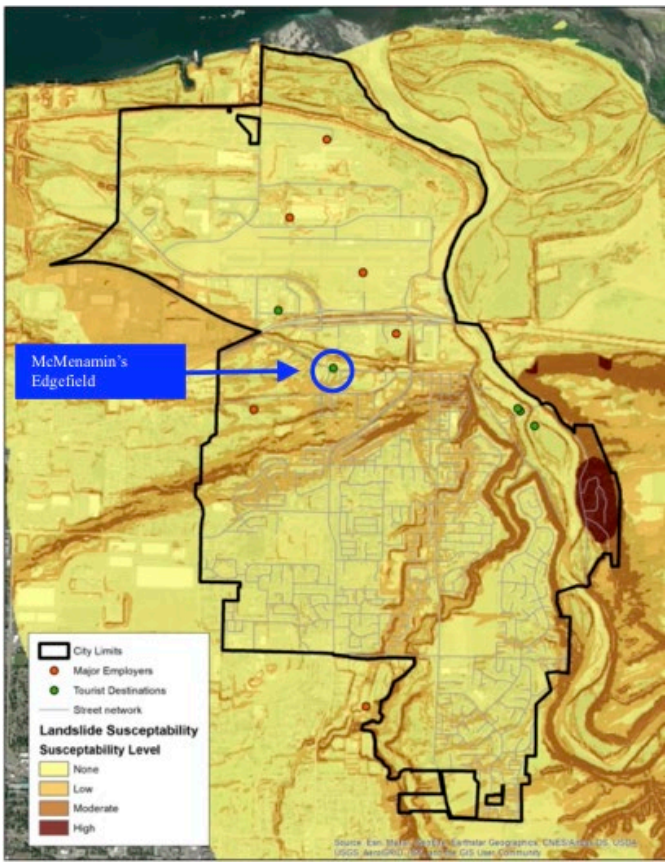
Risk level	Employers	Tourist Destinations	Commercial Buildings			R-1 Buildings		
			Count	Square Footage	Value	Count	Square Footage	Value
None	5	5	333	8,842,648	2,563,011,660	3289	8,433,324	1,684,642,410
Low	1	1	62	968,319	331,315,090	1367	15,525,992	1,674,445,820
Moderate	0	0	3	15,171	5,106,430	119	448,063	52,408,260
High	0	0	0	0	0	22	21,030	3,971,020

The first portion of the summary table worth noting is the commercial buildings. As Table 2 indicates, there are only three buildings out of 398 that are in the moderate-risk category and none in the high-risk category. These three buildings account for a little over $5 million in economic value, which in the grand scheme of the commercial presence in Troutdale is a low number. This shows us that there are very few commercial buildings and that this category of buildings and owners don't need to be prioritized in mitigation planning.

The next portion of this table to note is the R-1 building inventory. Considerably more buildings within this inventory are in the moderate and high-risk categories, with 22 R-1 buildings on the high-risk area of the historic landslide. These 22 buildings amount to nearly $4 million in value, and the 119 buildings within the moderate risk category amount to over $52 million. This combined $56 million is a significant number and should be prioritized over threatened commercial buildings.

The last takeaway from our economic analysis can be seen in Table 2 as well as Figure 2, as we look at tourist destinations and significant employers in Troutdale. This analysis shows that almost all of these locations lie within the no-risk category of landslide susceptibility. The only exception is one location for each, which is the same for each category and is McMenamin's Edgefield, is in the low-risk category. This is overall very positive for Troutdale, as little to no planning or policies are needed to protect the tourist destinations or major employers in Troutdale.

Figure 2. Employers and Tourist Destinations in Troutdale



3.2.2. Critical Infrastructure

Similar to the overall analysis, Troutdale's critical infrastructure is in relatively little danger of landslide disruption.

3.2.2.1. Emergency Infrastructure

The below table depicts the level of threat that Troudale's Medical, Police, Fire, and Shelter locations face. It is important to note that the scale of threat reaches no higher than "Low," indicating that Troutdale's EMS system is very safe from landslide risk. For the purposes of our analysis, "shelters" are any large retrofitted space that might serve the community during a natural hazard event. Additionally, it is also important to note that, while the chart says "Hospitals and Clinics," Troutdale only has clinics within the city boundary.

One of the two health clinics, the police station, and a little over 1/5th of the shelter locations are within the "Low Risk" areas. That being said, it would be beneficial for planners to evaluate this data as compared to the Transportation Infrastructure section (see 3.2.2.2.) and Network Analysis section (see 3.3.4), as people experiencing a hazard event would need the ability to access each facility in the first place.

Figure 3. Emergency infrastructure in Different Threat Levels

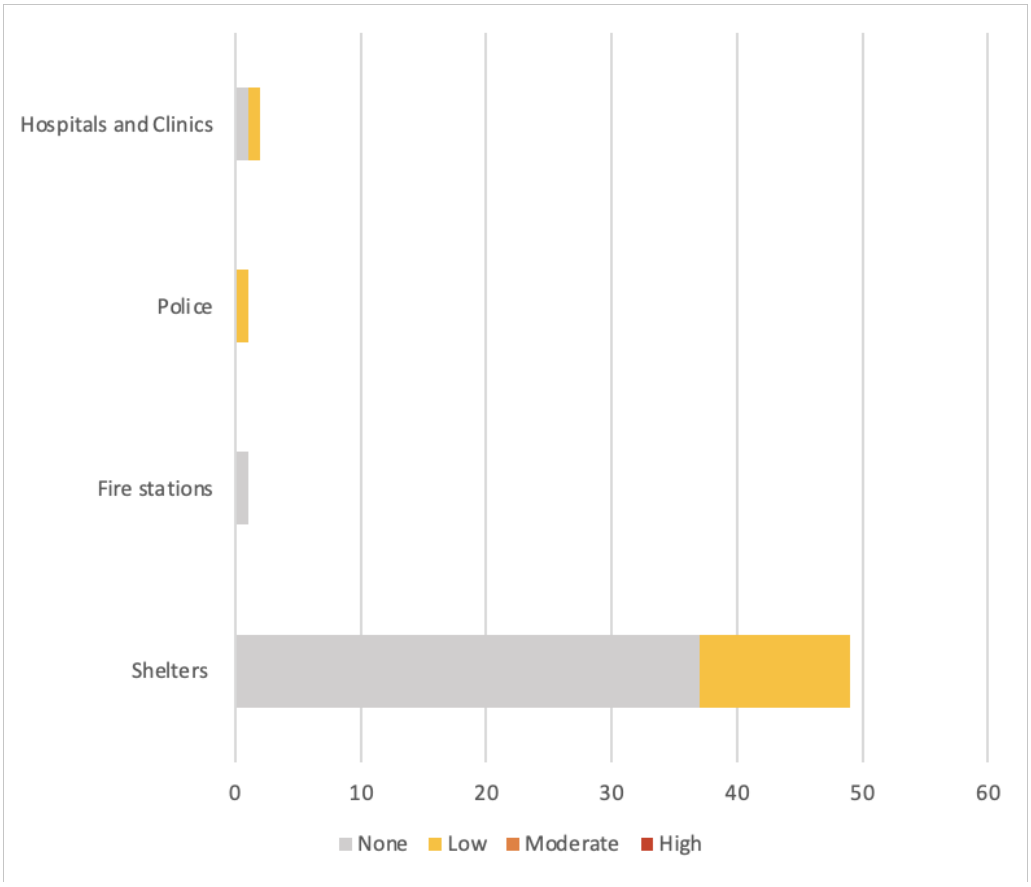


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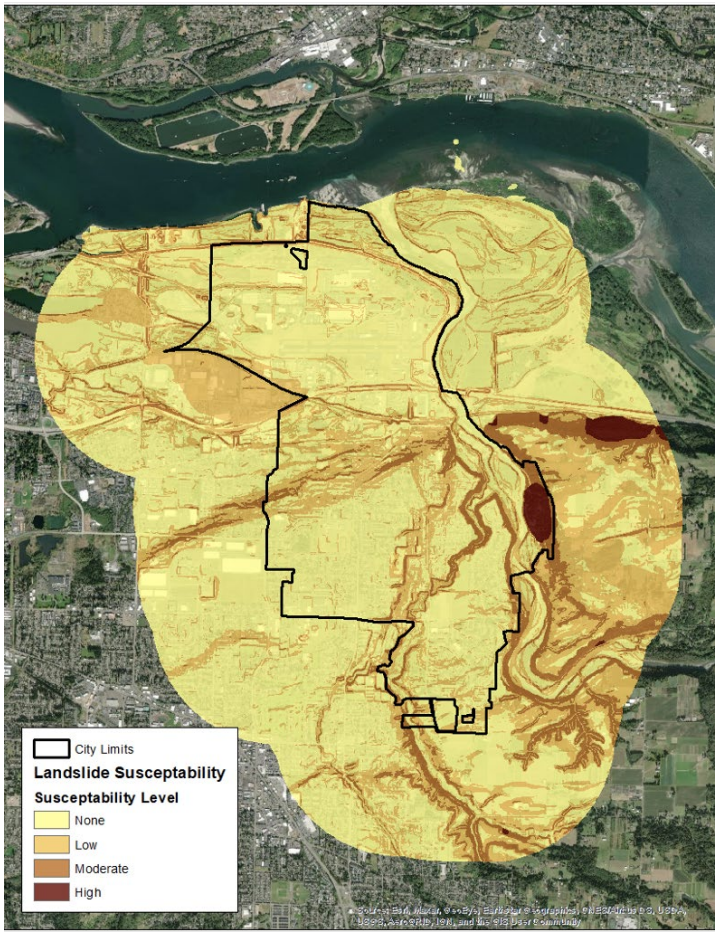
Table 1. Overall Landslide Susceptibility in Troutdale

Hazard Level	Percentage of Troutdale Land Within Risk Category
No Risk	60%
Low Risk	30%
Moderate Risk	9%
High Risk	1%

Beyond the numbers, we also can see how the landslide risk is distributed spatially throughout the city. Figure 1 shows an overview of Troutdale's landslide susceptibility throughout the city and buffer area.

Figure 1. Overall Landslide Susceptibility Map



The first area worth noting is the area of high risk on the eastern extremity of Troutdale's city limits. This area is a historic landslide and is the only area of high risk within the city boundary. This area's high-risk status comes from the disturbed soils that resulted from that historic landslide as well as the existing slopes of the region. It is worth noting that in addition to this former landslide, the majority of the region to the east of this high-risk area is higher in average risk level than the current Troutdale city limit area, which should be considered and analyzed in future Metro UGB expansion or urban reserve planning.

The second area worth noting due to its higher-than-average risk is the areas directly

adjacent to the Sandy River and Beaver Creek streambeds. As is apparent on the map, these areas are typically in the moderate risk category largely due to the high presence of water to erode the soil base as well as the higher slopes than much of the rest of Troutdale. These areas will be critical to plan for during floodplain management and flood hazard planning as flood events can increase the susceptibility for landslides compared to normal circumstances.

The third area to highlight is the bluff that runs from west-southwest to east-northeast across the portion of the city south of Interstate-84. This bluff has more low-risk and some moderate-risk areas that are largely due to the slopes of this bluff. While not a priority compared to the previous two zones, it should still be taken into consideration for landslide planning moving forward.

The final area to highlight is the portion of Troutdale situated between Interstate-84 and the Columbia River. This area is largely flat and lacks any significant stressing features, so it is almost entirely composed of the no-risk category. When planning for landslides, this area should be last on the list, and other hazards should be prioritized in this area.

To summarize our overall analysis of the landslide susceptibility in Troutdale, the vast majority of the city is in no-risk or low-risk areas. Particularly large sections of the city in the northern, southwestern, and southern regions lack any significant risk at all. The primary areas of risk are the historical landslide on the eastern extreme of the city boundaries and the slopes directly adjacent to the Sandy River and Beaver Creek. Landslide susceptibility can largely be covered in policies and targeted efforts in these regions, and tactical deployment of funds and staff to undertake these efforts on small scales can have a large impact on this hazard.

3.2. Community Assets

3.2.1. Economic Assets

An analysis of the economic assets we identified in Troutdale returns similar trends to the overall analysis, which is to say that landslide susceptibility threatens very limited amounts of the economic assets. To look at the whole of the economic asset analysis, we can refer to Table 2, which summarizes our data.

Table 2. Economic Asset Summary

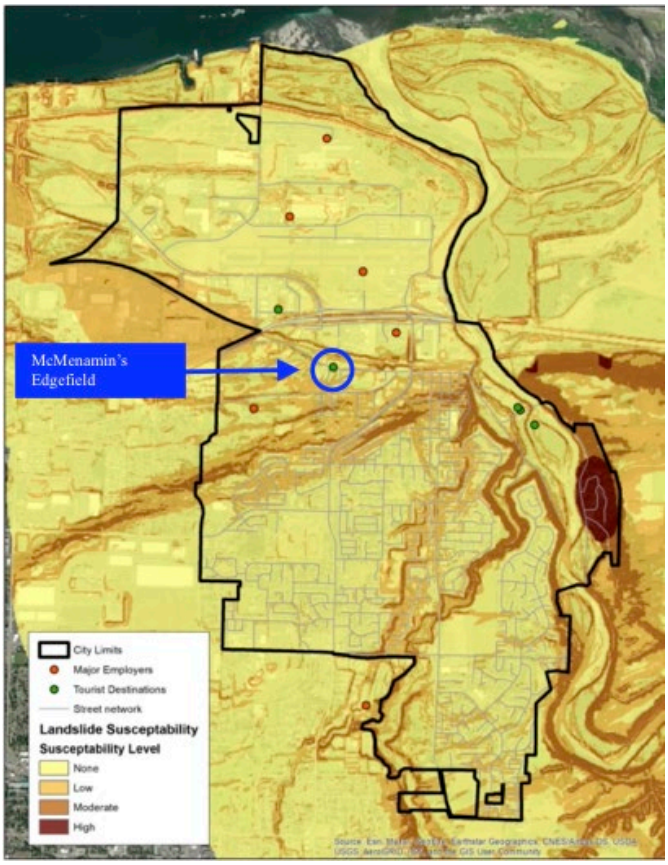
Risk level	Employers	Tourist Destinations	Commercial Buildings			R-1 Buildings		
			Count	Square Footage	Value	Count	Square Footage	Value
None	5	5	333	8,842,648	2,563,011,660	3289	8,433,324	1,684,642,410
Low	1	1	62	968,319	331,315,090	1367	15,525,992	1,674,445,820
Moderate	0	0	3	15,171	5,106,430	119	448,063	52,408,260
High	0	0	0	0	0	22	21,030	3,971,020

The first portion of the summary table worth noting is the commercial buildings. As Table 2 indicates, there are only three buildings out of 398 that are in the moderate-risk category and none in the high-risk category. These three buildings account for a little over $5 million in economic value, which in the grand scheme of the commercial presence in Troutdale is a low number. This shows us that there are very few commercial buildings and that this category of buildings and owners don't need to be prioritized in mitigation planning.

The next portion of this table to note is the R-1 building inventory. Considerably more buildings within this inventory are in the moderate and high-risk categories, with 22 R-1 buildings on the high-risk area of the historic landslide. These 22 buildings amount to nearly $4 million in value, and the 119 buildings within the moderate risk category amount to over $52 million. This combined $56 million is a significant number and should be prioritized over threatened commercial buildings.

The last takeaway from our economic analysis can be seen in Table 2 as well as Figure 2, as we look at tourist destinations and significant employers in Troutdale. This analysis shows that almost all of these locations lie within the no-risk category of landslide susceptibility. The only exception is one location for each, which is the same for each category and is McMenamin's Edgefield, is in the low-risk category. This is overall very positive for Troutdale, as little to no planning or policies are needed to protect the tourist destinations or major employers in Troutdale.

Figure 2. Employers and Tourist Destinations in Troutdale



3.2.2. Critical Infrastructure

Similar to the overall analysis, Troutdale's critical infrastructure is in relatively little danger of landslide disruption.

3.2.2.1. Emergency Infrastructure

The below table depicts the level of threat that Troudale's Medical, Police, Fire, and Shelter locations face. It is important to note that the scale of threat reaches no higher than "Low," indicating that Troutdale's EMS system is very safe from landslide risk. For the purposes of our analysis, "shelters" are any large retrofitted space that might serve the community during a natural hazard event. Additionally, it is also important to note that, while the chart says "Hospitals and Clinics," Troutdale only has clinics within the city boundary.

One of the two health clinics, the police station, and a little over 1/5th of the shelter locations are within the "Low Risk" areas. That being said, it would be beneficial for planners to evaluate this data as compared to the Transportation Infrastructure section (see 3.2.2.2.) and Network Analysis section (see 3.3.4), as people experiencing a hazard event would need the ability to access each facility in the first place.

Figure 3. Emergency infrastructure in Different Threat Levels

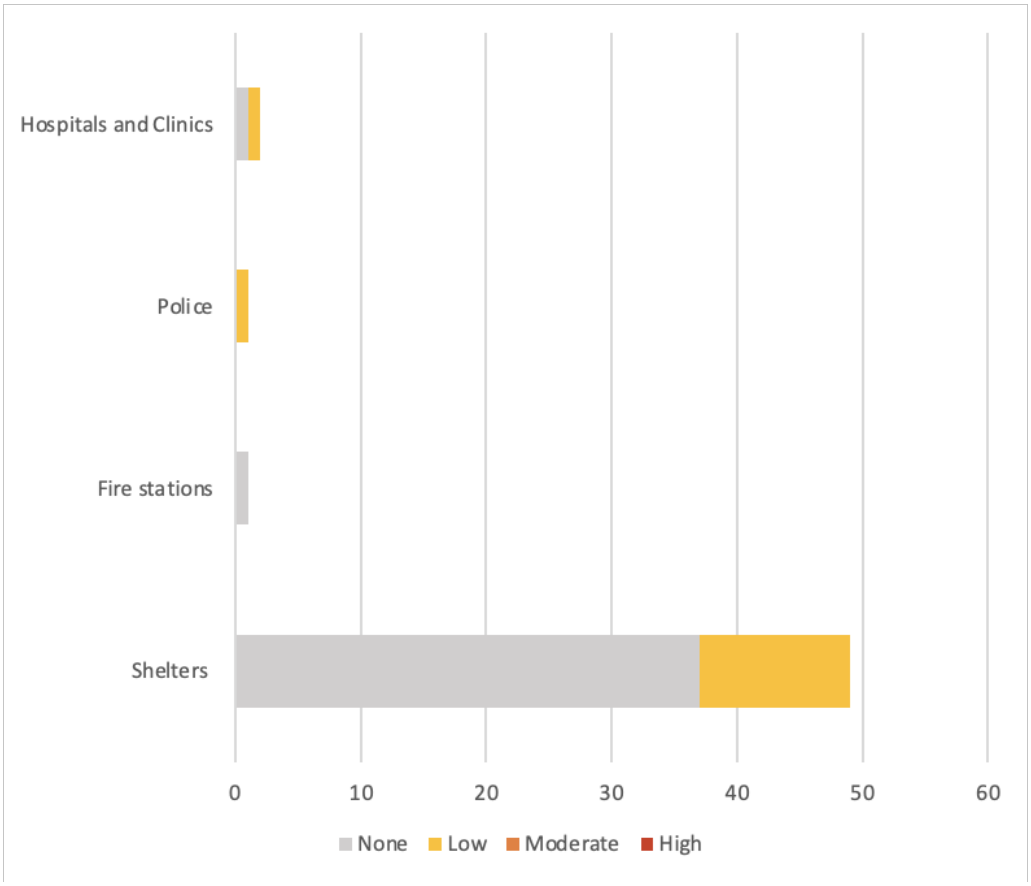
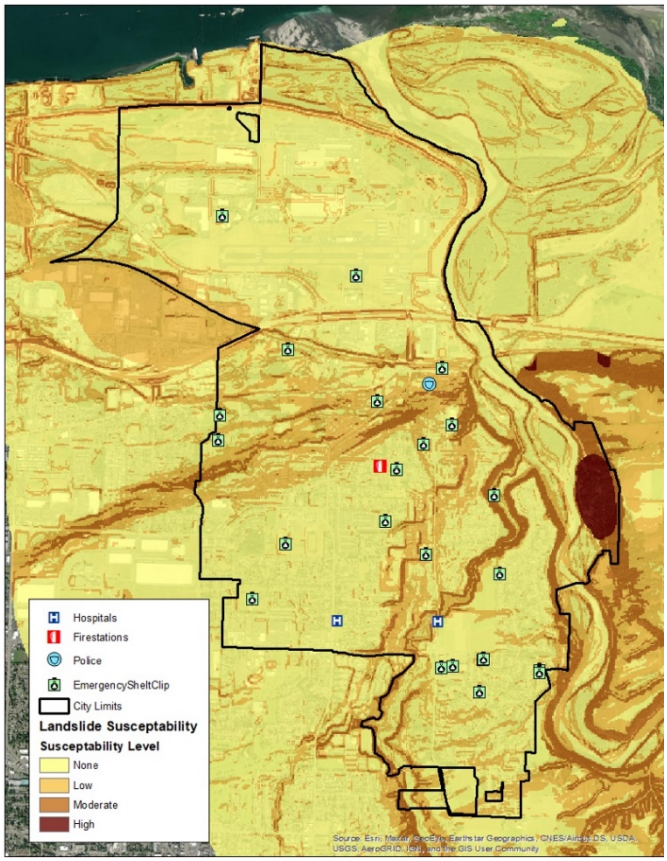
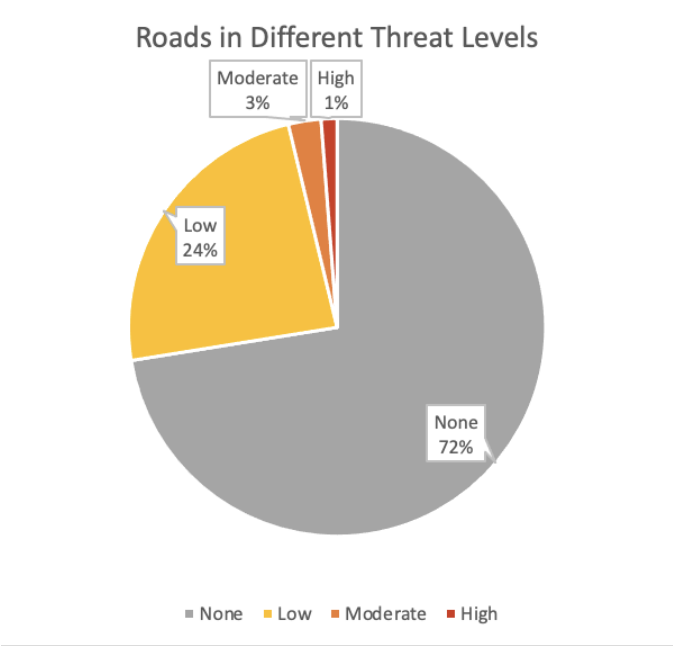


Figure 4. Emergency Infrastructure Map



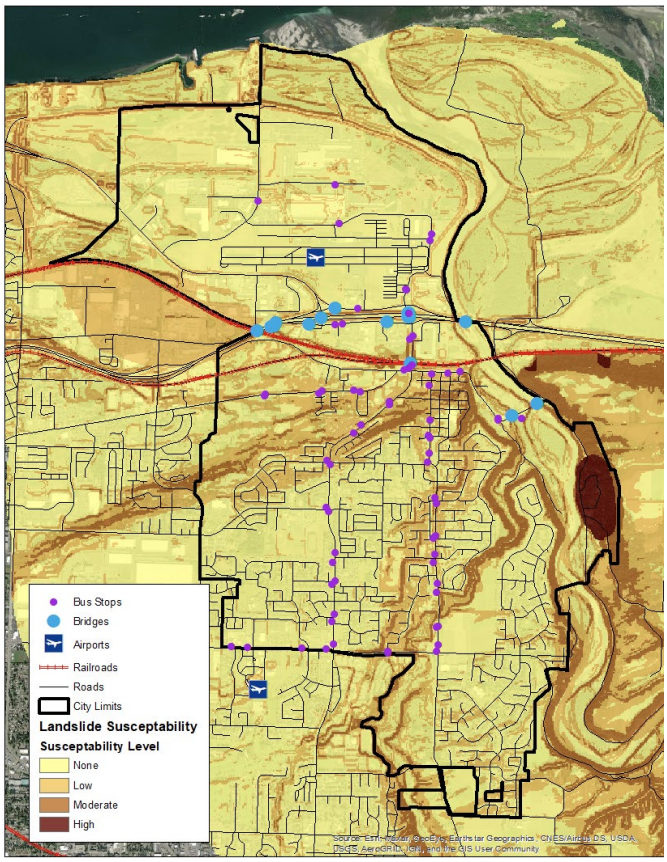
3.2.2.2. Transportation Infrastructure

Though 96% of Troutdale's road system has little to no risk of damage due to landslides, 3% has moderate risk, and 1% has high risk. Those areas of elevated risk align with our overall findings, as the roads in the most danger are located in the eastern high-risk area, adjacent to the Sandy River and Beaver Creek, and along the bluff that runs from west-southwest to east-northeast across the portion of the city south of Interstate-84.



Both the airport and city's bridges are in no to the low danger of landslides. The locations of TriMet bus stops' risk largely reflect the same levels of threat to the overall road network, though no bus stop is located within the "High Risk" areas.

Figure 5: Transportation Infrastructure Map



3.2.2.3. Utility Infrastructure

Of the Critical Infrastructure analysis, Utilities are at the most relative risk of landslide disruption. Table 3 breaks down the risks to stations and pipelines within Troutdale. While none of them are in high-risk areas, there are around 3 miles of piping that runs under areas of Moderate threat. As the pipelines are built into the road network, this closely mirrors the risk levels found in the above section. A big difference between the two maps is the fact that water/sewer appears not to run into the high-risk neighborhood on the eastern side of the Sandy River.

Table 3. Water and Sewer Risk

Risk Level	Pump/Sewer stations	Water pipes (Miles)	Sewer pipes (Miles)
None	6	49.78	41.74
Low	4	16.27	12.84
Moderate	0	1.29	1.81
High	0	0.00	0.00

Looking at Electricity and Gas Infrastructure in Table 4, most fall within areas of no to low risk. The only exceptions to this are the .63 miles of Transmission lines that run through moderate risk areas, and the .7 miles of a natural gas line that runs in moderate risk areas, and the .01 miles of the natural gas line runs under areas of high risk. In total, that brings only 1.34 miles of lines into the moderate or high-risk areas.

Appendix D

Earthquake Liquefaction Final Report

TROUTDALE HAZARD RISK AND VULNERABILITY ASSESSMENT -EARTHQUAKE LIQUEFACTION

SPRING 2021- ADVANCED URBAN GIS

Emily Connor
Melissa Graciosa
Eric Knudson
Olenka Wrobel

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PROJECT BACKGROUND AND RESEARCH OBJECTIVES

The goal of this project was to identify areas of Troutdale with higher exposure to natural hazards and map their spatial distribution. In focusing on earthquake liquefaction, we were able to understand the economic and social impacts of this particular hazard on the city and community. The project sought to inventory impacted facilities, infrastructure, and vulnerable populations and examine the location of those vulnerable community members in relation to the different liquefaction exposure levels. The research objectives included the following:

- Understanding earthquake liquefaction exposure in and around Troutdale.
- Assessing the economic value of critical infrastructure and green space in these risk zones.
- Providing recommendations for the City of Troutdale to mitigate potential damage to critical infrastructure from liquefaction hazards.
- Inventory affected facilities and estimate economic loss.

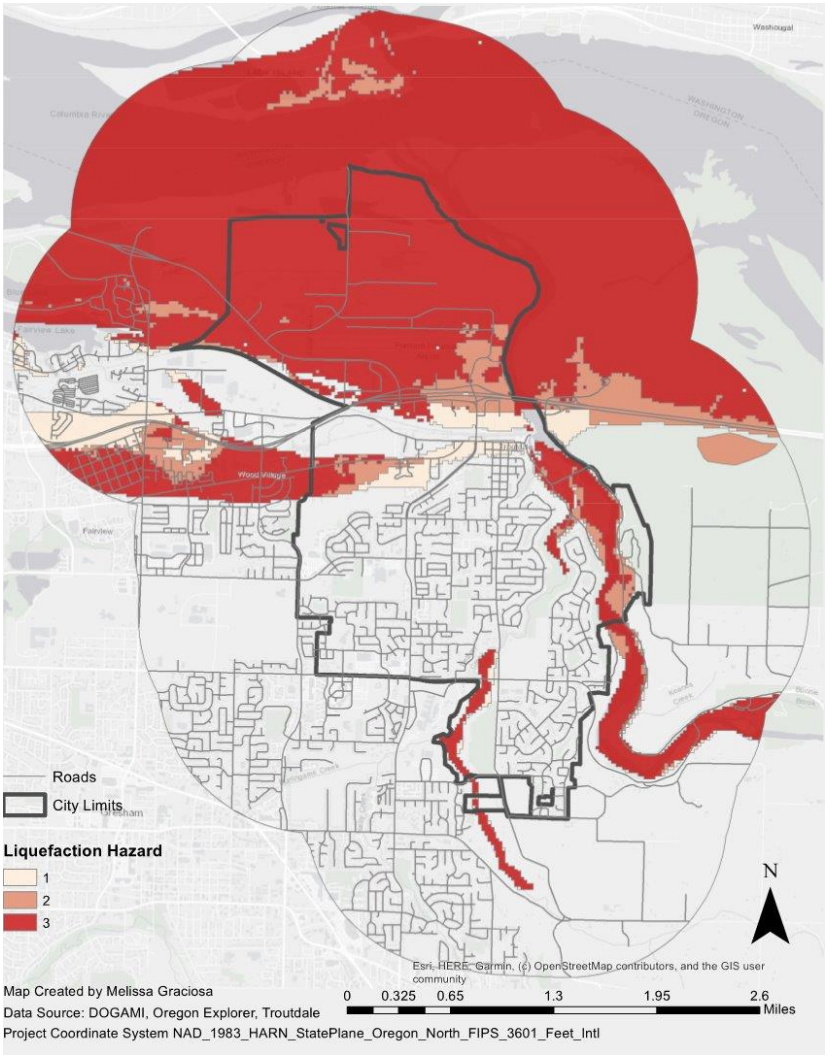
METHODOLOGY

STUDY AREA

The study area for this project was the city of Troutdale and a 1-mile radius around it. Facilities and assets within city limits were analyzed, while liquefaction exposure was analyzed in Troutdale and within the 1-mile radius.

DATA

The SCYP group analyzed hazard data, community assets, and community demographic information for this project. The Oregon Statewide Geohazards Viewer was used to get accurate earthquake liquefaction data. To ensure all community assets were being included, we used the City of Troutdale, Google Points of Interest (POI), and the Homeland



Infrastructure Foundation Level Data to obtain shapefiles and metadata to map these assets in GIS. Community assets included in this analysis are as follows:

- Economic Assets
- Critical Infrastructure
- Critical Facilities
- Natural Resources

The group looked at demographic data from the 2019 US Census and 2019 American Community Survey on the block group level to ensure our analysis was as granular as possible. While looking at this level, we were aware of the potentially high margin of error with some block groups or socio-economic categories. When analyzing vulnerable population data, we used the following indicators:

- Elderly population (65 years and older)
- Population under the age of 18
- Differently abled population
- Population below the poverty line

Using these indicators helps us understand where there are concentrations of people who may require additional services and support should a hazard event occur.

Analysis Process

The analysis process was iterative and started with a hazard assessment of Troutdale and the surrounding 1-mile area. After looking at the liquefaction exposure on its own, we mapped the social vulnerability indicators to understand spatially where the vulnerable populations were concentrated. Following this, we mapped point and polygon shapefiles of Troutdale's community assets. Once these were all mapped on their own and we understood their spatial distribution, we layered the social vulnerability and community assets on top of the hazard exposure layer to see if those vulnerable populations were in high exposure areas and the economic value of the critical infrastructure if different exposure levels. Doing the analysis this way helped the team synthesize our findings on a more granular level. The findings from this analysis process are in the following section.

SUMMARY OF FINDINGS

Overview

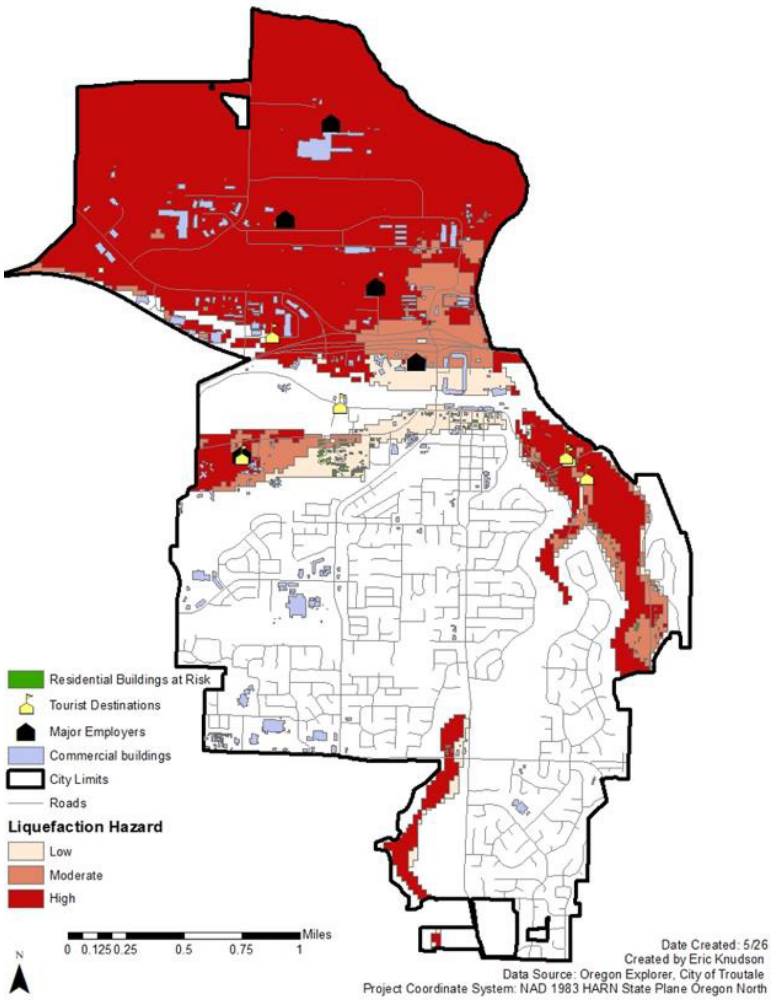
Liquefaction can occur underneath buildings and structures causing significant damage during earthquake events. Liquefaction susceptibility is the degree to which areas are vulnerable to earthquake liquefaction, assuming the ground is fully saturated. Liquefaction as a result of earthquake occurs when loosely packed, water-logged sediment at or near the ground surface loses strength. When looking at this hazard specifically, it is important to remember the frequency of these types of events when analyzing the hazard exposure for different areas of town. The findings below highlight key areas to focus on when looking at economic assets, critical infrastructure and facilities, natural resources, and vulnerable populations.

Economic Assets

The economic assets within Troutdale city limits include residential and commercial buildings, major employers, and tourist destinations. The map below shows the areas of high exposure to liquefaction hazard and the economic assets that fall within those areas. Many major employers and tourist destinations are in high exposure areas, especially in the northern part of town closer to the Columbia River. The commercial buildings – which include major employers- in high exposure areas, have an estimated economic value of $1.8 billion. Tourist destinations along the Sandy River are at a higher risk of liquefaction exposure and the economic value associated with these buildings is about $26.6 million. While these buildings are in higher exposure areas, more than half of the city has relatively low exposure to earthquake liquefaction and majority of residential buildings fall in low exposure areas.

Major Employers	
Company Name	**Risk Level**
McMenamins Edgefield	High
Columbia Gorge Outlets	Low
Troutdale Airport	High
Amazon	High
FedEx	High
Tourist Destinations	
Site Name	**Risk Level**
McMenamins Edgefield	High
Sugar Pine	High
Historic Mainstreet	None
Downtown	High
Sandy Riverfront RV Resort	High
Glenn Auto Community Park	High

Earthquake Liquefaction Risk by Economic Asset		
Commercial Buildings		
	Risk Level	**Estimated Economic Value**
	Low	$153,346,150
	Moderate	$274,507,470
	High	$1,864,760,570
Residential Buildings		
	Risk Level	**Estimated Economic Value**
	Low	$714,041,340
	Moderate	$18,844,110
	High	$27,514,940
Major Employers		
	Risk Level	**Estimated Economic Value**
	Low	$7,839,050
	High	$255,758,290
Tourist Destinations		
	Risk Level	**Estimated Economic Value**
	High	$26,665,190



Critical Infrastructure

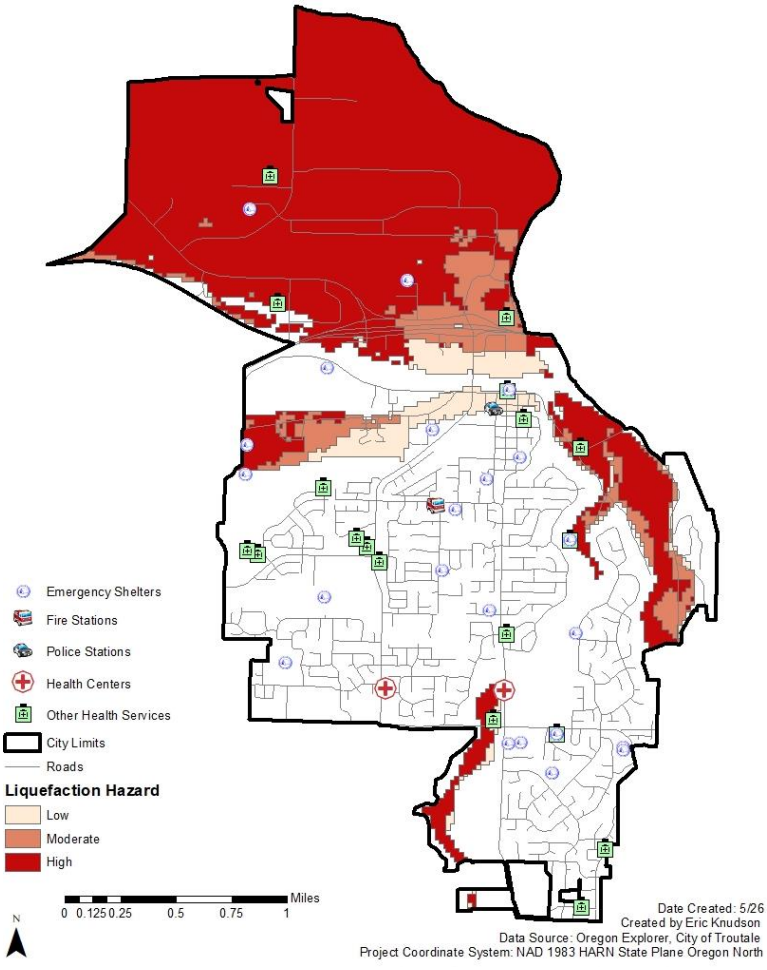
For this report, critical infrastructure was split into three different sections: emergency and hospital, transportation, and utilities.

Emergency and Hospital

When looking at emergency and hospital infrastructure, our studies were narrowed down to emergency shelters, fire stations, police stations, health centers and other health services. Our data indicates that Gresham Fire Department Water Rescue #75 is in an area of no threat. Next, our data indicates that both the Columbia View Family Health Center and the East County Veterans Clinic are also in an area of no threat. In contrast, our research concludes that there are three emergency shelters in liquefaction risk areas, all of which are in high-risk areas. These emergency shelters are ODOT Troutdale, Reynolds Online Academy, and One Stop Truck Service, which we identified to be an emergency shelter according to our data. In addition, we found that the Troutdale Sheriff's Operations Center is in a low-risk liquefaction area. Lastly, our findings conclude that there are six health service buildings in the risk area: (2) in low-risk areas: Luxe Hair Extensions by Sabrina Joy and Ja-Makin Me Tan, (1) in a moderate-risk area: Brookdale Troutdale and (3) in high-risk areas: Oprax Medical, Revive Skin Services and DOT Physicals Here. The summary table above presents our data analysis.

Earthquake Liquefaction Risk of Emergency + Health

	Risk Level	Estimated Economic Value	Total Sq. Feet	Count
Emergency Shelters				
	High	$13,193,310	32094	3
Police Stations				
	Low	$7,212,770	22896	1
Other Health Services				
	Low	$3,982,480	7192	2
	Moderate	$1,480,850	5496	1
	High	$12,130,850	26576	3



Transportation

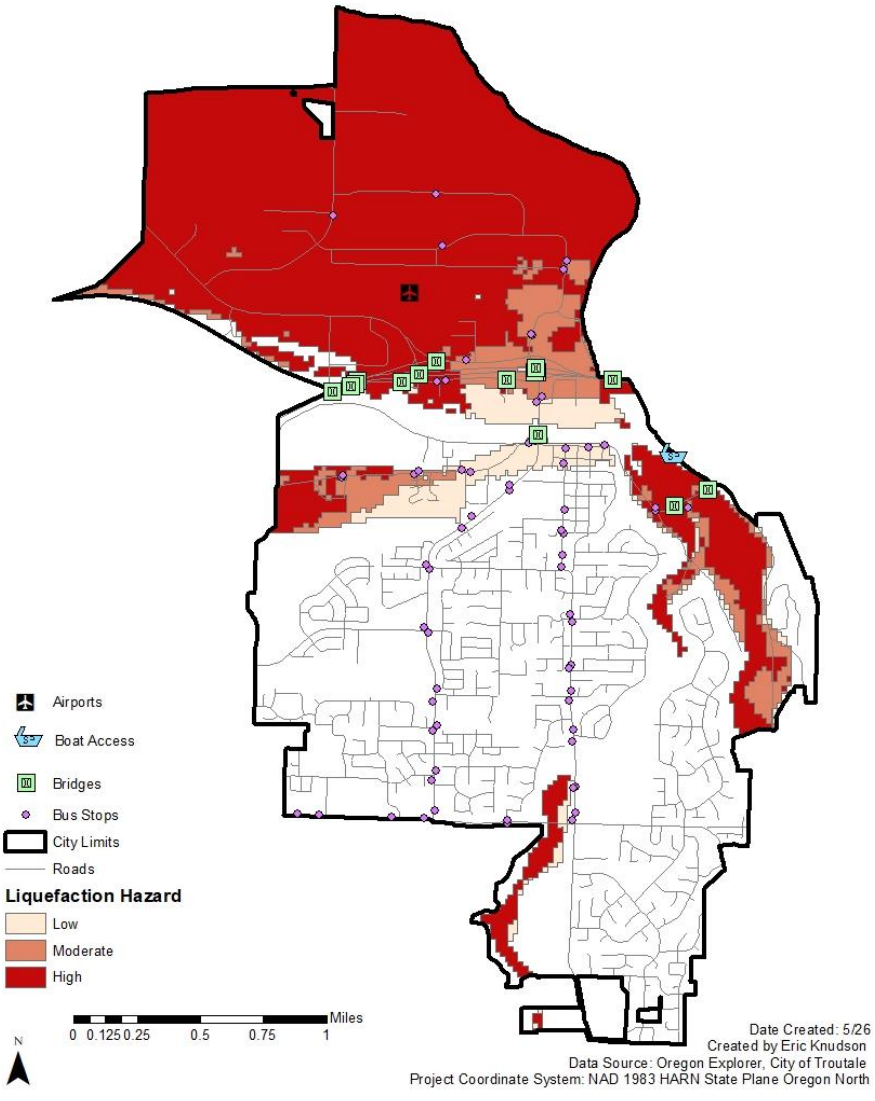
When analyzing transportation services, our studies focused primarily on bus stops and bridges, however we also included boating access for Lewis and Clark State Park and the Troutdale Airport. In our analysis, we found:

- Of the 75 bus stops in Troutdale, 33 are in areas at risk for earthquake liquefaction. Of these 33
    - 12 are in high-risk areas
    - 11 are in moderate-risk areas
    - 10 are in low-risk areas

As the map to the right illustrates, most of these bus stops are located on the north and east sides of the city.

- Of the 16 bridges in Troutdale, 14 are in areas at risk for earthquake liquefaction. Of the 14 bridges:
    - 9 are in high-risk areas
    - 5 are in moderate-risk areas

The airport and many of the city's major employers are separated from the city's health services and emergency response facilities by a series of bridges on the north side of the city. This raises concern about the response times of first responders and access to medical services in the event of a major earthquake.

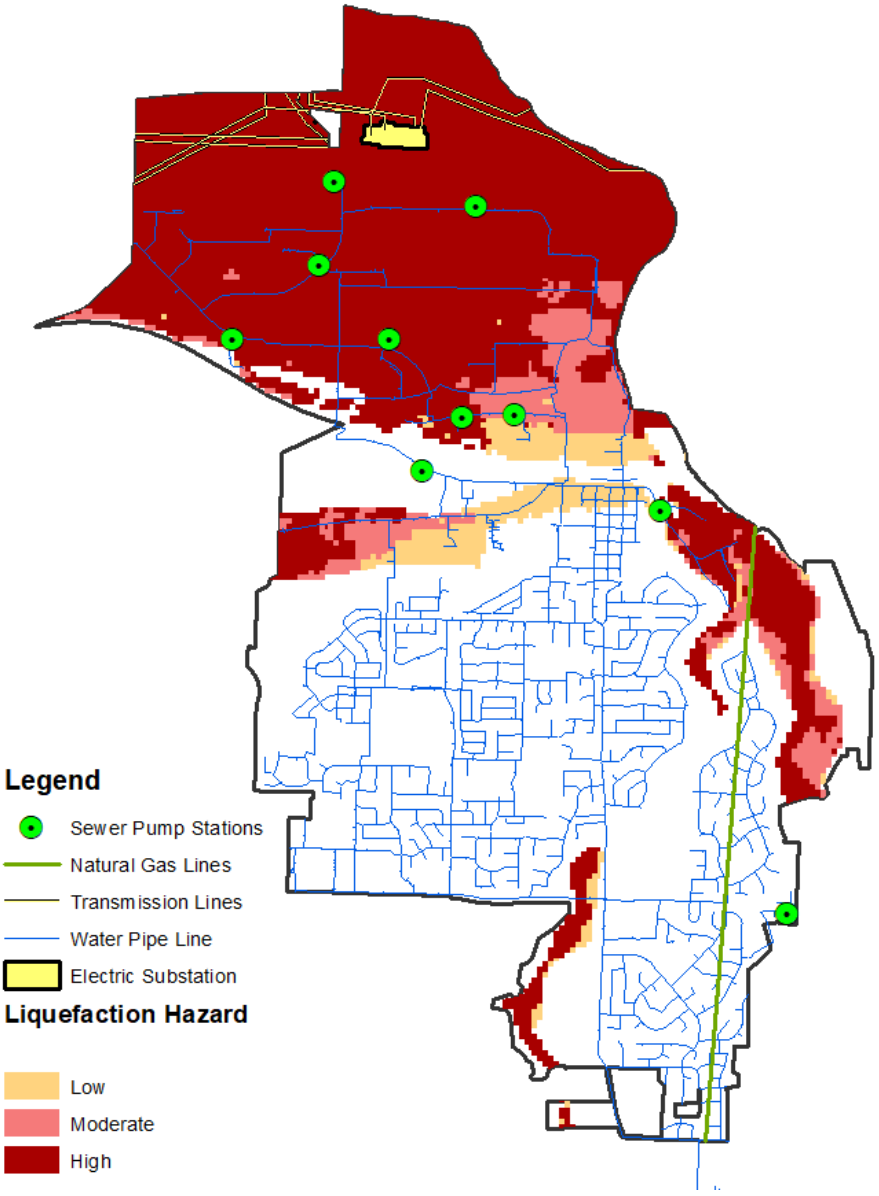


Utilities

For utilities, we looked at the systems that Troutdale has regarding sewer pump stations, water pipelines, transmission lines, electric substations, and natural gas lines all within city limits. Our findings are as follows:

- Out of nine sewer pumps, two are in no hazard risk, one is in moderate hazard risk, and the rest are in high liquefaction hazard
- 100% of the transmission lines and the electric substation are in the northmost high hazard area
- Natural gas line crosses high hazard area in its northern area
- Water pipelines on the north-side are in high-risk area.

Because of many of the utilities being located in the northern area of Troutdale, that puts them in high hazard risk of liquefaction. Diversifying location of utilities might be a consideration. Also ensuring that the utilities that do not exist in liquefaction hazard zones can handle increased capacity after an earthquake could be an added benefit.



Critical Facilities

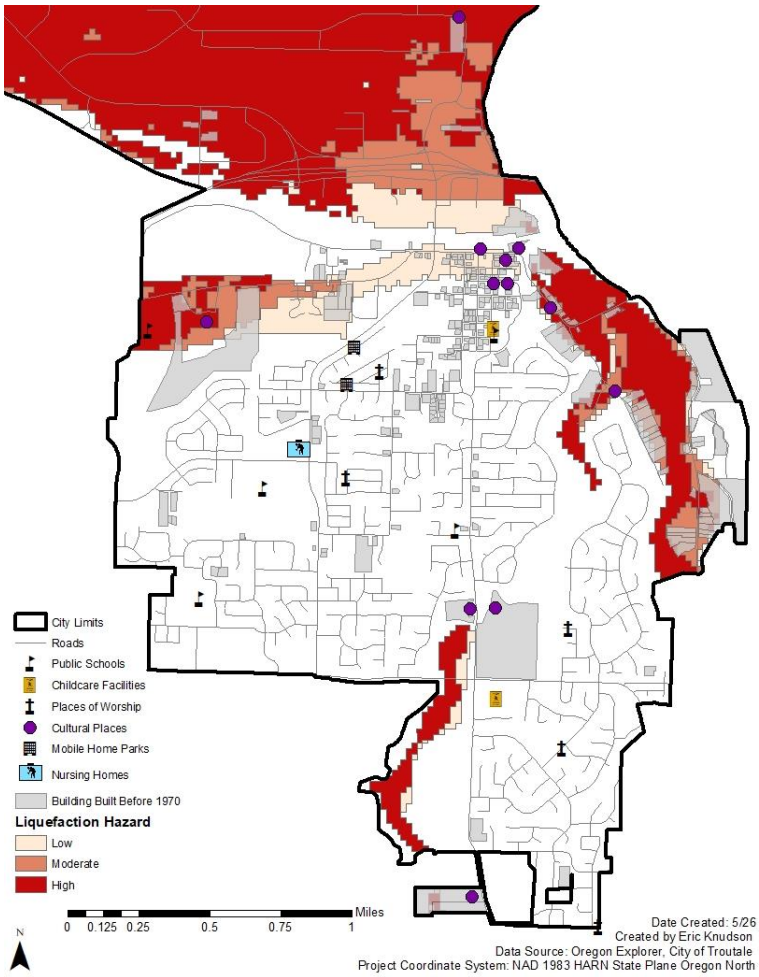
When looking at critical facilities, we analyzed the following: childcare facilities, nursing homes, mobile home parks, places of worship, public schools, and cultural places. In our analysis we found there to be no threats for childcare facilities, nursing homes, mobile home parks, or places of worship.

In contrast, we found several cultural places to be in various risk levels and one public school to be at risk for earthquake liquefaction. Arata Creek School and two cultural places (USACE Materials Laboratory and Multnomah County Poor Farm) in high risk. Two other cultural places in moderate risk (Beaver Creek Ridge and Barn Exhibit Hall). And the following cultural places are in low risk for liquefaction:

Earthquake Liquefaction Risk of Critical Facilities

Childcare Facilities			
Risk Level	**Estimated Economic Value**	**Square Footage**	**Count**
No Threats	$13,001,280	73,073	2
Nursing Homes			
Risk Level	**Estimated Economic Value**	**Square Footage**	**Count**
No Threats	$4,221,850	30,750	1
Mobile Home Parks			
Risk Level	**Estimated Economic Value**	**Square Footage**	**Count**
No Threats	$13,793,320	N/A	2
Places of Worship			
Risk Level	**Estimated Economic Value**	**Square Footage**	**Count**
No Threats	$8,870,140	N/A	5
Public Schools			
Risk Level	**Estimated Economic Value**	**Square Footage**	**Count**
No Threats	$63,787,940	214,204	4
High	$9,178,180	3,630	1
Cultural Places			
Risk Level	**Estimated Economic Value**	**Square Footage**	**Count**
No Threats	$4,337,420	15,424	8
Low	N/A	N/A	7
Moderate	$193,280	1,080	2
High	$19,905,220	4,880	2

- OR & N Railroad Main Line
- OR & N Railroad Bridge
- Bonneville Power Administration (BPA) Troutdale Substation
- Sandy River Diversion Dam
- Harlow House Museum
- Sandy River Bridge
- Baker, Alfred and Oceanna Farm



In the event of a major earthquake, there would be high concern for tourists visiting the cultural places, primarily the two locations in high-risk areas. Arata Creek School on the west side of the city is highly encouraged to evaluate preparation processes and infrastructural vulnerability.

Natural Resources

City parks, greenways, and agricultural land are all part of Troutdale's natural resources. Within city limits, there are two city parks and one greenway that are centered in liquefaction high threat areas. These resources are summarized in Table 5, which includes a total count of parcels and sum of square footage affected. These areas include Visionary Park, Harlow House Park, and South Beaver Creek. Harlow House is also a heritage resource.

Table 5. Natural Resource Threat Summary

Earthquake Liquefaction Risk of Natural Resources		
City Parks		
Risk Level	Square Feet	Count
High	322,344	2
Greenways		
Risk Level	Square Feet	Count
Low	588,060	3
High	56,628	1

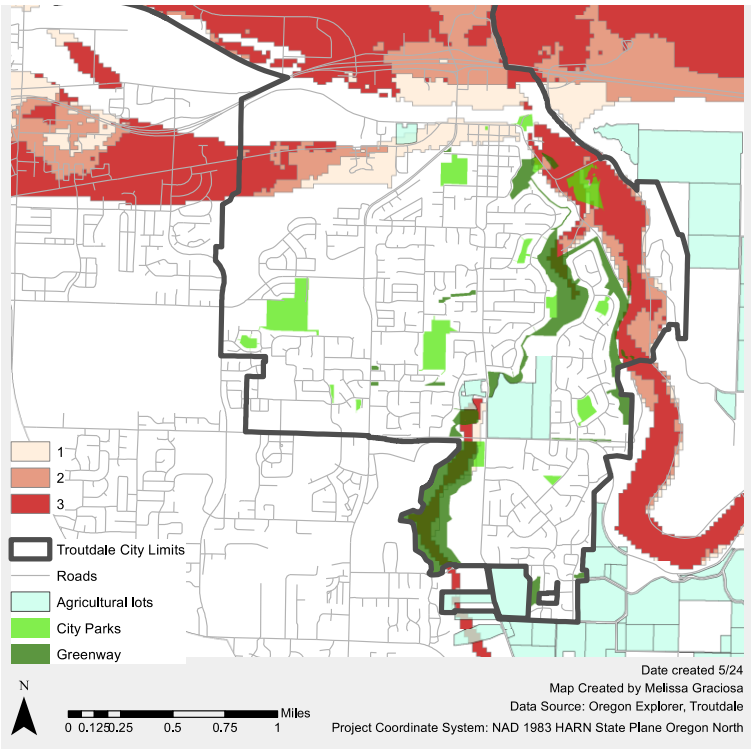
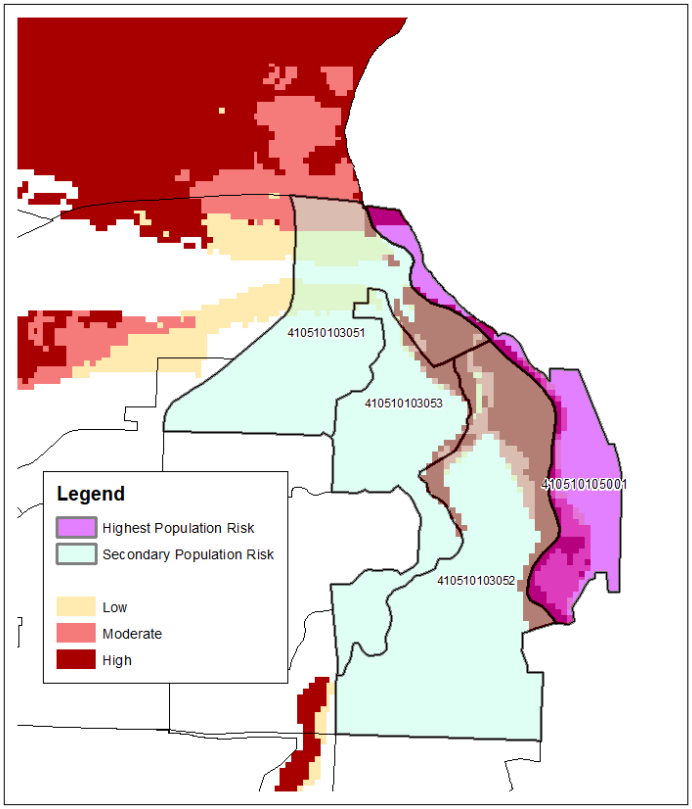


Table 6. lists resources that intersect with some level of liquefaction threat. Those listed are within city limits. Glen Otto Park is surrounded by high threat areas despite the center of the park being at low to no threat. Given how populated this park can be during the summer for the purpose of recreation, a liquefaction event may isolate individuals from resources to evacuate. The City may consider the ecological functions of natural resources when determining priority. Greenways may serve important ecological functions, such as flood control or habitat for sensitive plants and animals, that may compound with simultaneously occurring hazards. Lastly, agricultural lot property owners should be notified of the threat level that is posed to their properties and be encouraged to make plans accordingly. All agricultural lands did not have a value recorded to them within attribute tables. Further investigation to what the use of these properties is currently should be carried out.

Table 6. **Natural Resources that Intersect at any Level of Liquefaction**	
City Parks	Glen Otto Park College Nature Park
Greenways	Beaver Creek Greenway Bellingham Greenway Carolyn Taylor Natural Area
Agricultural lots	802 W Historic Columbia River Hwy 2511 S Troutdale Rd 2035 SE Troutdale Rd

Social Vulnerability

When looking at various forms of social vulnerability and liquefaction hazard, four census block groups rose to be of highest priority. Across all indicators (elderly population 65 and over, population under 18 years, differently abled, and below the poverty line), the highest number of people were located on the east side of Troutdale. Our analysis did not show any of these populations living in low, moderate, or high liquefaction hazards in the other block groups. The block group with the highest population across all vulnerable populations was the track on the other side of the river (also including area outside of Troutdale). The next three were those nearby with varying numbers of vulnerable populations.



Poverty

Est. Number of Persons in each Hazard Level				
GEOID	None	Low	Moderate	High
410510103031	300.0	0.0	0.0	0.0
410510103032	175.0	0.0	0.0	0.0
410510103051	244.7	24.7	4.0	8.6
410510103052	88.0	0.0	2.6	1.4
410510103053	86.7	2.6	0.4	4.3
410510103061	258.0	0.0	0.0	0.0
410510103062	154.0	0.0	0.0	0.0
410510103063	316.0	0.0	0.0	0.0
410510104022	27.0	0.0	0.0	0.0
410510105001	49.7	11.5	98.9	42.9

Elderly

Est. Number of Persons in each Hazard Level				
GEOID	None	Low	Moderate	High
410510103031	311.0	0.0	0.0	0.0
410510103032	264.0	0.0	0.0	0.0
410510103051	178.8	18.1	2.9	6.3
410510103052	202.7	0.0	6.1	3.2
410510103053	58.1	1.7	0.3	2.9
410510103061	93.0	0.0	0.0	0.0
410510103062	277.0	0.0	0.0	0.0
410510103063	90.0	0.0	0.0	0.0
410510104022	246.0	0.0	0.0	0.0
410510105001	49.5	11.4	98.4	42.7

Children

Est. Number of Persons in each Hazard Level				
GEOID	None	Low	Moderate	High
410510103031	782.0	0.0	0.0	0.0
410510103032	624.0	0.0	0.0	0.0
410510103051	268.1	27.1	4.4	9.4
410510103052	403.5	0.0	12.1	6.3
410510103053	195.6	5.8	0.9	9.7
410510103061	668.0	0.0	0.0	0.0
410510103062	330.0	0.0	0.0	0.0
410510103063	268.0	0.0	0.0	0.0
410510104022	684.0	0.0	0.0	0.0
410510105001	92.3	21.3	183.6	79.8

Disability

Est. Number of Persons in each Hazard Level				
GEOID	None	Low	Moderate	High
410510103031	225.0	0.0	0.0	0.0
410510103032	291.0	0.0	0.0	0.0
410510103051	118.0	11.9	1.9	4.1
410510103052	68.8	0.0	2.1	1.1
410510103053	71.0	2.1	0.3	3.5
410510103061	79.0	0.0	0.0	0.0
410510103062	147.0	0.0	0.0	0.0
410510103063	86.0	0.0	0.0	0.0
410510104022	38.0	0.0	0.0	0.0
410510105001	11.8	2.7	23.4	10.2

DISCUSSIONS AND CONCLUSIONS

Earthquake liquefaction poses the highest threat to resources located in the northern part of Troutdale. These include major area employers, commercial and industrial buildings and infrastructure, and critical facilities such as a school, materials laboratory, and Edgefield (Multnomah County Poor Farm). Commercial buildings under threat have a cumulative worth of $1.8 billion in economic assets. Along the Sandy River and Beaver Creek, greenways are at high threat to liquefaction as well as vulnerable populations reside in residential areas near these water ways. Both locals and visiting tourists at one of Troutdale's more popular park, Glen Otto Park, recreate in a high threat to liquefaction area. A liquefaction event would cause a significant economic blow, both locally and regionally, as well as increase the number of people in within high threat area during hours of operation.

Our project team provides the following recommendations, summarized below, for preparation, mitigating, and preventing the disaster impacts from a liquefaction event. Troutdale should consider which recommendations may align with other hazards to leverage the City's capacity to increase disaster resilience. Preparing for some chronic hazards, such as floods or fire, can work to increase catastrophic hazards, such as liquefaction. Ultimately, the priority in the event of a liquefaction hazard will be to prevent the loss of life and property; actualizing preparation and mitigation recommendations can work to support response and recovery at a later date.

Liquefaction Recommendations
Preparation Strategies
• Increase awareness of high-threat/high-vulnerability residents • Encourage pocket response plans, back-up supplies, awareness of evacuation routes, and personal evacuation plans   • Public awareness workshops
• Signage on hazards and evacuation routes at tourist destinations
• Identify and coordinate city-level emergency response partners   • Consider non-traditional partners in emergency management – economic development practitioners, heritage resource organizations, community organizations
• Identify alternative evacuation routes when I-84 is impacted by hazard
• Mandate preparation and evacuation plans for commercial businesses within high threat zones   • Communicate with regional partners that have workers commuting to Troutdale at major employment centers

Mitigation/Prevention Strategies
• Land use codes can be used to limit future development in high-threat areas, especially for populations at high vulnerability
• Identify funding for retrofitting of transportation, utility, and emergency infrastructure
• Identify funding for retrofitting of commercial and industrial property
• Partner with city or county level organizations to provide housing options or shelter locations away from high-risk hazard areas

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